PB82-168972

# Five-Year Research Plan for Effects of Noise on Health

(U.S.) Environmental Protection Agency
Washington, DC

Dec 81

U.S. Department of Commerce
National Technical Information Service
NTIS

PB82-168972

# FIVE-YEAR RESEARCH PLAN FOR EFFECTS OF NOISE ON HEALTH

OFFICE OF NOISE ABATEMENT & CONTROL
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

## TECHNICAL REPORT DATA

*(Please read Instructions on the reverse before completing)*

**1. REPORT NO.**

**2.**

**3. RECIPIENT'S ACCESSION NO.** PB82 168972

**4. TITLE AND SUBTITLE** Five-Year Plan for Effects of Noise on Health

**5. REPORT DATE** December 1981

**6. PERFORMING ORGANIZATION CODE** 054161

**7. AUTHOR(S)**

**8. PERFORMING ORGANIZATION REPORT NO.** EPA 550/9-82-101

**9. PERFORMING ORGANIZATION NAME AND ADDRESS**

U.S. Environmental Protection Agency
Office of Noise Abatement and Control
Washington, D.C. 20460

**10. PROGRAM ELEMENT NO.**

**11. CONTRACT/GRANT NO.**

**12. SPONSORING AGENCY NAME AND ADDRESS**

**13. TYPE OF REPORT AND PERIOD COVERED**

**14. SPONSORING AGENCY CODE**

**15. SUPPLEMENTARY NOTES**

**16. ABSTRACT**

This Plan, a revision of an earlier unpublished "EPA Five-Year Noise Effects Research Plan," is intended to serve as a blueprint for future research by other organizations. In addition to introducing categories of health effects of noise and setting priorities for new research, it include detailed plans for the following categories: nonauditory physiologic effects, particularly, cardiovascular effects; sleep disturbance; individual and community response; noise-induced hearing loss behavioral, social and performance effects; and communication interference. Each plan proceeds from what is known, the research priorities, and results of recent research to arrive at a detailed plan including Multi-Component Research Initiatives.

**17. KEY WORDS AND DOCUMENT ANALYSIS**

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| environmental noise<br>noise control<br>public health planning<br>health research<br>noise-induced hearing loss sleep<br>hypertension | Cardiovascular disorders<br>physiologic stress<br>communication interference<br>environmental health | |

| | | |
|---|---|---|
| **18. DISTRIBUTION STATEMENT**<br>Permission is granted to reproduce this material without further clearance | **19. SECURITY CLASS** *(This Report)*<br>UNCLASSIFIED | **21. NO. OF PAGES**<br>172 |
| | **20. SECURITY CLASS** *(This page)*<br>UNCLASSIFIED | **22. PRICE** |

EPA Form 2220-1 (9-73)

EPA 550/9-82-101

# FIVE-YEAR RESEARCH PLAN FOR
# EFFECTS OF NOISE ON HEALTH

December 1981

Office of Noise Abatement and Control
U.S. Environmental Protection Agency

Permission is granted to reproduce this material without further clearance.

A

# TABLE OF CONTENTS

**Contents** **Page**

Executive Summary . . . . . . . . . . . . . . . . . . . . . . . . E-1

1. Introduction. . . . . . . . . . . . . . . . . . . . . . . . . . 1-1
   1.1 Legislative and Programmatic Requirements for Research . . 1-3
   1.2 Goals of the Health Effects Research Program . . . . . . . . 1-7
   1.3 Reader's Guide to the Research Plan. . . . . . . . . . . . . 1-11

2. Overall Priorities for a Noise Effects Research Plan. . . . . . 2-1
   2.1 Overall Results of Priority Analysis . . . . . . . . . . . . 2-2
   2.2 Level of Emphasis A. . . . . . . . . . . . . . . . . . . . . 2-3
      2.2.1 Nonauditory Physiologic Effects . . . . . . . . . . . 2-3
   2.3 Level of Emphasis B. . . . . . . . . . . . . . . . . . . . . 2-7
      2.3.1 Sleep Disturbance . . . . . . . . . . . . . . . . . . 2-7
      2.3.2 Individual and Community Response . . . . . . . . . . 2-9
   2.4 Level of Emphasis C. . . . . . . . . . . . . . . . . . . . . 2-14
      2.4.1 Noise-Induced Hearing Loss. . . . . . . . . . . . . . 2-14
      2.4.2 Behavioral, Social and Performance Effects. . . . . . 2-17
   2.5 Level of Emphasis D. . . . . . . . . . . . . . . . . . . . . 2-20
      2.5.1 Communication Interference. . . . . . . . . . . . . . 2-20

3. The Research Plan in Detail (Introduction). . . . . . . . . . . 3-1
   3.1 Definition of Long-range Objective . . . . . . . . . . . . . 3-1
   3.2 Definition of Short-term Objectives. . . . . . . . . . . . . 3-1
   3.3 Definition of Research Initiatives . . . . . . . . . . . . . 3-2
   3.4 Concept of Evolution in Research (the Research Continuum). 3-6
   3.5 Contents of the Research Plan for Each Category. . . . . . . 3-9
   3.6 Nature and Direction of Research Findings. . . . . . . . . . 3-9
   3.7 Guidance and Monitoring. . . . . . . . . . . . . . . . . . . 3-9

*4. Research Plan for Nonauditory Physiologic Effects . . . . . . . 4-1

*5 Research Plan for Sleep disturbance . . . . . . . . . . . . . . 5-1

*6 Research Plan for Individual and Community Response . . . . . . 6-1

*7 Research Plan for Noise-Induced Hearing Loss. . . . . . . . . . 7-1

*8 Research Plan for Behavioral, Social and Performance Effects. . 8-1

*9 Research Plan for Communication Interference. . . . . . . . . . 9-1

10. Summary and Integration . . . . . . . . . . . . . . . . . . . . 10-1
   10.1 Reserach Initiatives in which Work is Currently in. . . . Progress. . . . . . . . . . . . . . . . . . . . . . . . . . 10-1
   10.2 Integrated Schedule of Expected Results . . . . . . . . . . 10-4
   10.3 Interaction of Proposed Research with Ongoing Noise Control Activities. . . . . . . . . . . . . . . . . . . . . 10-5
   10.4 The Future . . . . . . . . . . . . . . . . . . . . . . . . . 10-11

---

* See the detailed Table of Contents for each of the Research Plans. These can be found at the beginning of Chapters 4 through 10.

## LIST OF TABLES

| Table | Title | Page |
|---|---|---|
| E-1 | Noise Effects Research Funding by Agency | E-7 |
| 3-1 | Priority Research Initiatives Included in This Plan | 3-3 |
| 3-2 | Secondary Research Initiatives | 3-4 |
| 3-3 | Research Continuum in the Development and Requirement of Health Effects Criteria | 3-7 |
| 3-4 | Items Included in the Plan for Each Research Category | 3-10 |
| 4-1 | Position on the Research Continuum - Nonauditory Physiologic Effects | 4-9 |
| 5-1 | Position on the Research Continuum - Sleep Disturbance | 5-8 |
| 6-1 | Position on the Research Continuum - Individual and Community Response | 6-7 |
| 7-1 | Position on the Research Continuum - Noise-Induced Hearing Loss | 7-11 |
| 8-1 | Position on the Research Continuum - Behavioral, Social and Performance Effects | 8-8 |
| 9-1 | Position on the Research Continuum - Communication Interference | 9-7 |
| 10-1 | Research Initiatives Receiving EPA Support in Fiscal Years 1980-82 | 10-2 |
| 10-2 | Integrated Schedule of Expected Results by the End of Fiscal Year 1982 | 10-6 |
| 10-3 | Integrated Schedule of Expected Results After Research Initiatives are Completed (within Approximately Five-Year Time Frame) | 10-8 |

## LIST OF FIGURES

| Figure | Title | Page |
|---|---|---|
| E-1 | Noise Effects Research Funding by Category | E-6 |
| 4-1 | Sequencing of Nonauditory Physiologic Effects Research | 4-26 |

# EXECUTIVE SUMMARY

A Noise Effects Research Plan was first submitted in 1980 as one of two subplans to be integrated into a Five-Year EPA Noise Program Plan. The Five Year Plan (Fiscal Year 1981-1985) was requested in legislation pending before Congress in the fall of 1979. That Plan has been updated herein to reflect progress to date and the current direction of the national environmental noise control effort. The Plan can now be used as a blueprint of future research needed to support State, local and Federal noise control activities. The identified Research Initiatives should be undertaken if comprehensive and useful noise-effects criteria are ever to be developed, and if the public is to feel confident that major health effects are being addressed in planned noise control actions. The Plan can function as a valuable reference source for use by other organizations in planning their own noise effects research programs.

The Research Plan expresses an overall goal, "to improve the noise-related Health and Welfare data base, refine existing criteria, and develop quantified dose-response criteria where they are lacking." The application of this data base and criteria will provide a more accurate assessment of noise-related health effects, will aid in determining the need for specific noise control actions, will provide a basis for public officials to ascribe benefits to all noise control actions and to set protective and cost efficient levels, and will enhance the development and effective implementation of community ordinances and noise control plans.

This document presents specific research objectives for six major categories of noise-related health effects, which either serve as the foundation for existing criteria or have the potential for being incorporated into new health effects criteria. The overall priorities of the Plan are given below, ranging from A (the highest priority) to D (the lowest priority):

(A) Nonauditory Physiological Effects
(B) Sleep Disturbance
(B) Individual and Community Response
(C) Noise-Induced Hearing Loss
(C) Behavioral, Social, and Performance
(D) Communication Interference

These categories have been ranked based on the following five evaluation factors: (1) Severity of the particular health problem, (2) Environmental Noise Control Program Needs, (3) Scientific Recommendations, (4) Feasibility, and (5) Appropriateness. These factors are further defined in Chapter 2. The prioritized categories of research have been endorsed as well by the National Academy of Sciences, the International Commission on Biological Effects of Noise, and by a consensus of Federal agencies involved in noise effects research. The highest priority category is research on Nonauditory Physiologic Effects. The major focus of research in this category is to verify the extent to which cause-effect relationships exist between noise and stress-related diseases, such as cardiovascular disease.

Noise as a stressor is a suspected factor in hypertension and potential heart disease. There are several epidemiological studies which support this relationship. In addition, EPA's primate study at the University of Miami has demonstrated a sustained elevation of blood pressure on the order of 30 percent after exposure to noise levels representative of normal human daily activities. The possible implications from a public health standpoint greatly magnify the importance of assigning the highest priority to this area of study. If the planned research program in this category is pursued over the next few years, it should verify the extent to which noise/physiologic health relationships exist and, therefore, possibly change both the direction and importance of Federal, State and local noise control activities.

The (B) priorities, Sleep Disturbance and Individual and Community Response, are areas which have a large bearing on noise abatement strategies and actions. Most people at one time or another have been annoyed by various noise sources, and have also had their sleep disrupted by noise. These consequences, which are caused by a combination of both acoustic and nonacoustic factors, may be characterized as a denigration of general health, behavior, and work performance. Since millions of Americans, especially susceptible populations (elderly, the ill, and others), live in localities where these detrimental noise effects are prevalent, research in these areas is considered especially important.

The reader is directed to Chapter 2 for added discussion in these subjects plus other priorities (C) and (D) noted above. For example, in the area of Noise-Induced Hearing Loss, an important research issue is the degree to which environmental noise exposure contributes to the significant prevalence of hearing impairment in the United States. In the area of Behavioral, Social and Performance Effects, one major concern is the effects of noise on the cognitive and social development of children.

Chapter 3 identifies various Research Initiatives for the prioritized categories, showing the need for related animal, human, and epidemiological studies. Research Initiatives funded by EPA over the first two years of the Plan are listed, as well as other prioritized Initiatives which are recommended for funding. Chapter 3 provides a background discussion of all definitions in the Plan, the conceptual layout of the plans for each research category, and the coordination and monitoring requirements which are necessary for the periodic review of the research program and the dissemination of results to other Federal agencies and to the scientific community.

Chapters 4 through 9 present detailed research plans for the identified priorities and Initiatives under each research category. These chapters are organized to present a rationale for selecting the specific Research Initiatives which cover: the status of research to date; priorities specifically related to supporting Federal, State and local programs for abatement of environmental noise; current Federal research activities; and a list of the most important Research Initiatives which are not at present being funded. Contained within each chapter are detailed descriptions of the Research Initiatives, related research of other Federal agencies, and a description of other Initiatives which, although integral to the environmental noise control effort, are deemed to be of secondary priority.

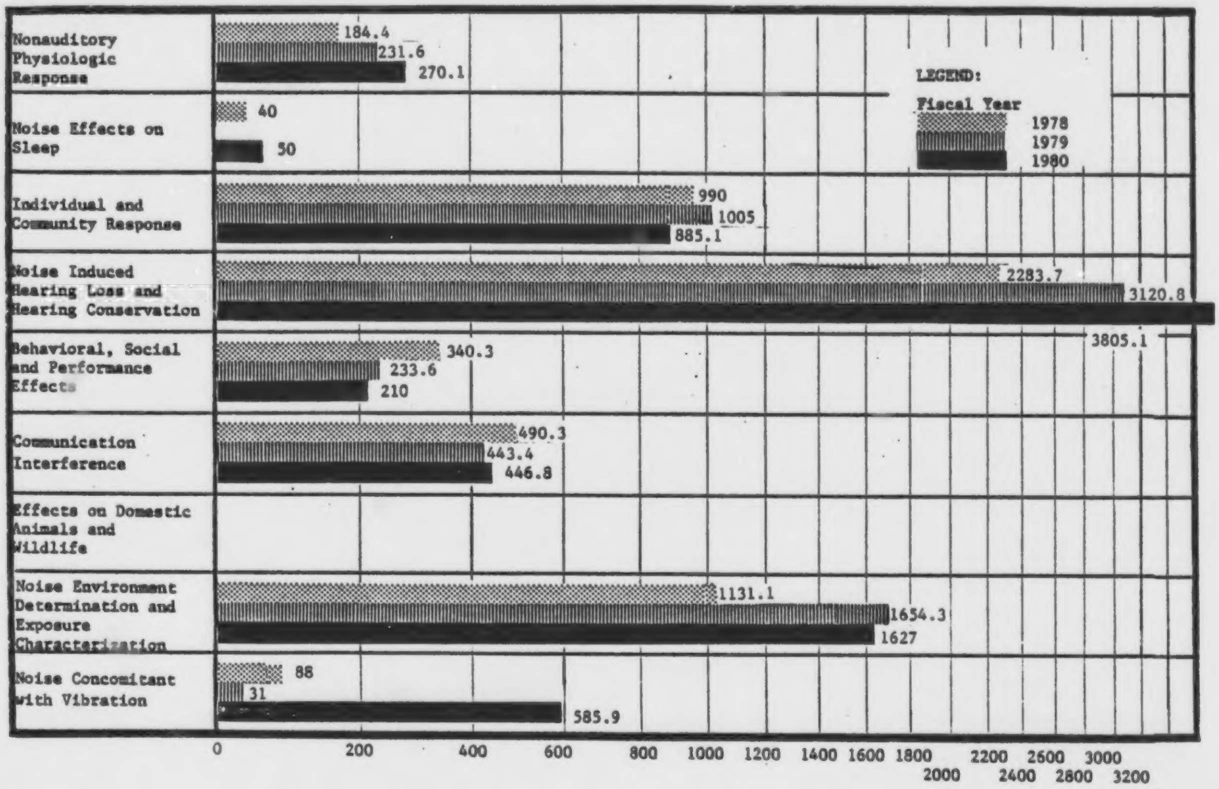
Figure E-1 portrays Federal funding figures for noise effects research in each research category over the past three years (FY 1978-80). Table E-1 shows the average amounts each Federal agency has been spending in support of noise effects research. Chapters 4 to 9 will describe how the identified Initiatives relate to the specific research plans and activities of other Federal agencies.

The last chapter (10) pulls together information on the proposed Research Initiatives, year by year, so that for any year the total array of research activities, milestones and results can be identified, compared and discussed across all of the health effects categories. Table 10-1 presents a concise listing of Research Initiatives for all categories. Table 10-2 presents an integrated schedule of expected results by the end of each fiscal year over the Five Year Plan period, with the assumption that work under the proposed Initiatives is undertaken. It is the prospect of these results which will greatly refine and expand health effects information and criteria.

In 1980 the EPA Office of Noise Abatement and Control presented the first draft of the original Plan to the Interagency Advisory Group on Noise Effects Research for review. This Group is comprised of members from the National Institutes of Health, Department of Labor/Occupational Safety and Health Administration, Department of Defense, Department of Transportation, National Aeronautics and Space Administration, National Bureau of Standards, and the National Science Foundation. Overall, the Advisory Group endorsed the Plan

Figure E-1. NOISE EFFECTS RESEARCH FUNDING BY CATEGORY

(In thousands of dollars)



## Table E-1. NOISE EFFECTS RESEARCH FUNDING BY AGENCY
(In thousands of dollars)

| AGENCY | FISCAL YEAR | | | TOTAL |
|---|---|---|---|---|
| | 1978 | 1979 | 1980 | |
| DEPARTMENT OF AGRICULTURE: U.S. Forest Service | 107 | 72.4 | 33 | 212.4 |
| DEPARTMENT OF COMMERCE: National Bureau of Standards | 75.5 | 12.5 | 72.5 | 160.5 |
| DEPARTMENT OF DEFENSE: U.S. Air Force | 913.8 | 965.8 | 996.7 | 2876.3 |
| U.S. Army | 1196 | 1779 | 1865 | 4840 |
| U.S. Navy | 274.4 | 518.1 | 578 | 1370.5 |
| DEPARTMENT OF EDUCATION: Bureau of Education of the Handicapped | | 18.8 | | 18.8 |
| DEPARTMENT OF ENERGY | 180 | 200 | 200 | 580 |
| ENVIRONMENTAL PROTECTION AGENCY | 328.2 | 339.9 | 680.8 | 1348.9 |
| DEPT. OF HEALTH AND HUMAN SERVICES: Center for Disease Control: NIMH | 14.4 | 6.6 | | 21 |
| NIOSH | 341.5 | 538.1 | 907.6 | 1787.2 |
| Food and Drug Administration | | 2.2 | | 2.2 |
| Health Services Administration | 36.2 | | | 36.2 |
| National Institutes of Health: NHLBI | | 51.4 | 41.1 | 92.5 |
| NICHHD | 38.7 | 19.7 | | 58.4 |
| NIEHS | 171 | 273 | 269 | 713 |
| NINCDS | 695.7 | 821.4 | 789.3 | 2306.4 |
| DEPARTMENT OF THE INTERIOR: U.S. Bureau of Mines | | | 282 | 282 |
| DEPARTMENT OF LABOR:<br>Mine Safety & Health Admin.<br>Employment Standards Admin. | 57.2 | 217.8 | 561 | 836 |
| NATIONAL AERONAUTICS & SPACE ADMIN. | 698 | 648 | 392 | 1738 |
| NATIONAL SCIENCE FOUNDATION | 56.7 | 38 | 36 | 130.7 |
| DEPARTMENT OF TRANSPORTATION | 358.9 | 197 | 176 | 731.9 |
| VETERANS ADMINISTRATION* | 5 | | | 5 |
| YEARLY TOTALS | 5548.2 | 6719.7 | 7880 | |
| TOTAL | | | | 20147.9 |

*Veterans Administration Noise Research is primarily done with no special programmatic funding.

as scientifically credible, aligned to current research needs, and indeed feasible. EPA/ONAC received a similar positive opinion from selected national noise effects experts who were consulted on the prioritization of Initiatives to meet long-term noise control and research needs. The Plan was also reviewed by the National Organization of Noise Control Officials (NANCO) made up of State and local environmental noise control officials throughout the U.S. The organization praised the Plan stating that it "is extremely important to State and local noise programs in that the results will establish a significant portion of the foundation for noise control efforts and regulations." Therefore, the Plan has been received positively by a wide spectrum of the scientific and noise control communities and is presented herein in an updated version.

# 1. INTRODUCTION

From 1971 to the present, the Environmental Protection Agency (EPA) has been active in the effort to protect people from excessive noise that may jeopardize their health and welfare. Under the requirements of the Noise Control Act of 1972, as amended by the Quiet Communities Act of 1978, EPA has been required to conduct research on the effects of noise on health, for the ultimate purpose of developing dose-response criteria. These criteria have been needed to support all aspects of environmental noise control program activities, including Federal regulations and technical assistance to State and local governments.

As part of this research effort, EPA developed the "EPA Five-Year Noise Effects Research Plan" in February 1980. It was envisaged that the Plan would serve as a blueprint for EPA-sponsored research for the next five years, as well as outlining how EPA research would dovetail with other ongoing Federally-sponsored research to fill critical research gaps.

Over this past year, a basic realignment in national policy has occurred, resulting in an increased role for state and local noise activities and a decreased role for Federal noise programs. As part of this change, the sponsorship of noise effects research by EPA will be phased out by the end of fiscal year 1982. Consequently, EPA is now in the process of completing its ongoing studies and has updated its Five Year Health Effect Research Plan for Noise.

The updated Research Plan as presented here contains a current summary of the state of knowledge with respect to the effects of noise, and a detailed presentation of prioritized areas of needed research in terms of a series of major initiatives and their respective components. EPA, with some assistance from other Federal agencies, has already begun to execute selected elements within the initial phases of the plan. Several important studies have been initiated, and some results are available now, with additional results expected by the end of fiscal year 1982.

It is EPA's intention that the enclosed Plan and the initial results of studies conducted under the Plan serve as a stimulus for other Federal agencies, and the states and research organizations to continue needed research into the effects of noise on health.

One of the most important outgrowths of the Plan is that it establishes a framework for use by other agencies planning their own noise effects research efforts. The basic structure and layout of the Plan can be used as a viable model by other agencies. Secondly, the Plan provides substantive guidance on the types of research that are necessary to meet many of the public health and welfare needs of all environmental noise abatement programs, whether on the Federal, State or local level. Overall, the Plan provides a good starting point for establishing more coordinated and unified noise effects research programs with better focus, direction and insight for maximum utilization of available expertise and resources. The Plan should function as a valuable reference source for future planning purposes.

At the present time, the Plan has been updated to reflect: (1) the progress that has been made in carrying out EPA's research program in the prioritized research categories, and (2) the current direction of Federal, State and local environmental noise control activities and research needs. It is hoped that many of the high priority Research Initiatives discussed in the Plan will be carried out over the next five years.

This introductory chapter is devoted to discussing the legislative mandates, overall environmental noise control research goals, the importance of noise related health effects research in developing and supporting environmental noise control policy, and the specific research categories and research needs of environmental noise control programs, all of which were factors in shaping the Plan.

## 1.1 Legislative and Programmatic Requirements for Research

The Noise Control Act of 1972, as amended by the Quiet Communities Act of 1978, recognized that specific information concerning the effects of noise on people was critically needed in order for EPA to carry out its mission to coordinate activities in noise control, to establish Federal noise emission standards for products distributed in commerce, to require the labeling of some of these products, to assist States and localities in establishing effective noise control programs, and to provide information to the public reflecting the hazardous effects of noise, and on noise levels associated with such effects.

To that end, the Act (as amended) required EPA to:

> "Conduct or finance research...including but not limited to investigation of the psychological and physiological effects of noise...and determination of dose-response relationships suitable for use in decision making, with special emphasis on the nonauditory effects of noise." (Sect. 14(6)).

These requirements represent a substantial expansion of noise effects research responsibilities from those originally set forth in the Noise Control Act of 1972.

Even without these specific legislative requirements, research with respect to the effects of noise on public health is required to support Federal, State and local noise control needs. On that account a health effects research strategy should be responsive to the health related needs inherent in a comprehensive national noise control effort. Elements of concern in the development of a health effects research strategy include: (1) the development and enforcement of environmental noise legislation, (2) the provision of technical assistance to State and local noise control efforts, (3) the dissemination of information to the public on the health effects of noise, (4) research and demonstration of advanced noise control technology, and (5) the coordination of noise control activities and health effects research among Federal, State and local agencies, and technical organizations.

The quantification of the health-related effects of noise is necessary in the development of all noise related legislation or regulations at the Federal, State and local governmental levels, because the purpose of such legislation is to protect the public health and welfare. Citizens and public officials alike need to be adequately informed as to the health consequences of noise exposure in order to make rational, efficient, and cost-effective social decisions to secure a healthy environment. Research is fundamental to: (1) establishing information on the incidence and severity of health-related effects such as hearing loss, nonauditory physiologic effects, and sleep disturbance; (2) developing human response criteria to quantify the effects and health consequences of noise; (3) ascertaining a cause-effect relationship due to specific source environments, and (4) helping to promote the harmonization of existing governmental standards and guidelines.

This last point deserves elaboration. Other Federal agencies such as the Department of Transportation, the Department of Defense, and the National Aeronautics and Space Administration presently support their noise control activities with research programs which investigate both the direct and indirect health effects caused by exposures to different types of noise. In many instances, the human response criteria developed by one agency are incorporated into those standards and policies of another agency. Ultimately there should be one set of health-related criteria used by all agencies. Agencies would then develop noise-related policy under their respective authorities, using these criteria based upon specific health implications as well as social, legal, and economic considerations. However, the foundation of noise-related policy must rest on an understanding of basic health and welfare effects.

EPA has had extensive experience in monitoring and coordinating the noise effects research of all Federal agencies over the past few years. In 1977, EPA reconvened a panel of representatives from Federal agencies which conduct or support noise research, to review the status of all Federal research activities with respect to the health effects of noise, and to recommend areas where further research was needed. The Panel found that over 19 agencies, or major organizations within agencies, were conducting health effects research at a total funding level of approximately six million dollars annually.* EPA conducted relatively little of this research ($190K to $349K in Fiscal Years 1975-1977).

Updated research project and funding summaries were collected again in 1980** from all Federal agencies conducting noise effects research during the Fiscal Years 1978 to 1980. This more recent information presents substantially the same picture (see Table E-1 and Figure E-1 in the Executive Summary). The number of active agencies, or major organizations within agencies, conducting noise-related health effects research has grown to 23. Over the Fiscal 1978-1980 period, annual research expenditures averaged approximately $6.7 million. EPA still conducted a small but integral part of this research, mostly focused on the Nonauditory Physiologic Effects research category ($328K in Fiscal Year 1975, $340K in Fiscal Year 1979, $681K in Fiscal Year 1980, and $741K in Fiscal Year 1981).

Thus, while each agency's noise-related research might adequately support its own limited mission and goal, the 1977 Panel found that, taken in its totality, the overall pattern of research on noise effects contained numerous gaps in the health effects data base and limitations in existing human response criteria. More recent information suggests that the picture has not changed. Although some health effects criteria are already being applied, other potentially severe health consequences of environmental and occupational noise exposures are not being adequately addressed. The Panel report recommended that steps be taken to fill these gaps. To that end, EPA and other Federal agencies have initiated several research projects (described in Chapters 4-9). The Panel report has also been instrumental in the design of the health effects research strategy contained in this Plan, and the specification of numerous research priorities.

---

* Federal Noise Research in Noise Effects, EPA Report 550/9-79-102, February 1978.

** Federal Noise Research in Health Effects 1978-1980, December 1980.

## 1.2 Goals of the Health Effects Research Program

The overall goal of the health effects research program is stated below. This goal is based on: (1) the fundamental importance of health effects information in support of noise control legislation and policies; and (2) knowledge of the status of existing health and welfare criteria and data.

Overall goal: To improve the noise-related health and welfare data base, refine existing criteria, and develop quantified dose-response criteria where they are lacking.

Only through the development of quantified dose-response criteria can a thorough understanding of the health implications of noise be obtained, and health benefits be properly ascribed to all noise control actions, whether taken on Federal, State or local levels.

The overall research program goal stated above has been broken down into a number of specific objectives for the various identified categories of noise effects research. The research categories used are similar to those cited in the previously discussed EPA Panel Report. Further, Research Initiatives have been developed in the present strategy to meet these specific objectives. Each Initiative is expressed in terms of one or more research projects, evolving in a time-phased manner, to answer major research questions in a defined area. In determining the content of the Research Initiatives, EPA considered the specific programmatic applications of any research finding to particular noise control activities undertaken by other Federal agencies, State and local communities, or the private sector.

EPA has had a responsibility to make the latest research results available to both the general public and to State and local noise control officials in order collectively to meet our nation's noise control needs. For example, the public is more likely to make informed decisions regarding the purchase of quieter consumer products or even the selection of a location to live when they have more detailed information on the adverse health effects of noise. Citizens need more information to make decisions regarding their own personal noise exposures. Public officials need more information to set into motion the necessary programs to improve the quality of the noise environment. State and local officials need additional health effects information and refined criteria in order to set the most protective but cost-efficient levels in order to strengthen their noise regulations and policies. They must have the necessary health-related information to determine what degree of noise control is needed and should be considered in the many routine administrative actions that touch each of our lives every day such as building codes, comprehensive land use planning, traffic management, municipal purchasing decisions, zoning variances, enforcement of laws, and vehicle inspections.

Accordingly, the following categories of noise effects research are specified. There are six major categories of noise-related health effects which either (1) presently serve as the foundation for existing criteria or (2) have the potential for being incorporated into specific noise effects criteria, provided that the necessary research is undertaken and dose-response relationships established. These categories of research are presented with their accompanying research objectives.

A. Nonauditory Physiological Effects--to determine and quantify the nonauditory effects on bodily systems and on general health, with special emphasis on hypertension and other cardiovascular effects.

B1. Sleep Disburbance--to determine and quantify effects of noise on sleep, and its implications for general health and performance.

B2. Individual and Community Response--to determine and quantify subjective reactions of individuals and communities to different environments and sources, investigating mediating factors.

C1. Noise-Induced Hearing Loss--to determine the extent of the problem, causative factors, and associated effects.

C2. Communication Interference--to determine and quantify the effects of noise on communications and its developmental, social and other implications.

D. Behavioral, Social and Performance--to determine and quantify the effects of noise on social behavior, mental health, and human performance.

It should be pointed out that the above-stated objectives are long-term. However, some information is available as a first step in meeting a few of these objectives. Accordingly, the specific Research Initiatives described herein are designed to meet the identified objectives in each category focusing on the most important gaps and deficiencies in our understanding.

There are three additional areas of noise-related research that have not been identified: exposure characterization, vibration, and effects on wildlife. The objective of exposure characterization is to determine patterns of noise exposure, typical noise doses attributable to different sources and/or environments, and the health-related consequences of these exposures. More complete and accurate descriptions of the public's noise exposures are needed in order to determine the related auditory and nonauditory health effects. The proposed Research Initiatives in each health effects category inherently require the complete documentation of the subject's daily noise exposures at work, in transit, in the community, and at home. Since this requirement is common to all of the noise-related health effects categories, separate Research Initiatives for exposure characterization were not proposed.

Vibration associated with noise is also a significant source of annoyance and discomfort. As discussed in the 1977 Panel report, the relative contributions of noise and vibration need to be assessed in order to derive criteria for the combined exposure conditions. However, vibration effects have not been listed separately within this

Research Plan, but instead are contained as an intrinsic consideration within each of the six categories of noise effects research. It should also be mentioned that there is some ongoing Federally-sponsored health-related research concerning the effects of vibration, most notably by the U.S. Air Force, the U.S. Army, and the National Aeronautics and Space Administration.

The effects of noise on wildlife is a research area which will continue to require attention, particularly in the preparation of environmental impact analyses. The concern with this research category is maintaining livable habitats for species that may be vulnerable to noise effects, and to assure balance within the ecosystem. There is very little ongoing research in this area. However, this research category was considered outside the scope of this Plan.*

It should be noted that this Health Effects Research Plan is not intended to constitute a full program of needed research. While the proposed Research Initiatives address most of the highest priorities, they do not represent a comprehensive research program. Such an effort would require a combined approach of much greater magnitude.

## 1.3 Reader's Guide to the Research Plan

The body of this Research Plan consists of a set of Plans, one for each category of noise effects research.

Chapter 2 explains how priorities were set for the Research Plan.

---

* For further information see: Effects of Noise on Wildlife and Other Animals--Review of Research Since 1971, EPA Report 550/9-80-100, July 1980.

Chapter 3 presents an introduction to the specific Research Plan for each category, and defines concepts such as "Research Initiative" and "Research Continuum" which are common to all of the Plans.

The specific Research Plans for each category of noise effects are presented in Chapters 4 through 9. Each chapter contains an overview of the current status of research and health effects information and a selected set of first-priority Research Initiatives. Additional worthwhile Initiatives of secondary priority are also identified.

Chapter 10 provides aggregate and summary data on the entire Plan.

## 2. OVERALL PRIORITIES FOR A NOISE EFFECTS RESEARCH PLAN

This Plan outlines a concrete operational Plan for noise effects research over a five-year time frame, commencing in Fiscal Year, 1981. The first step in developing the Research Plan was to establish priorities for the six categories of research previously identified. Although each category and its respective research objective was felt to be important in its own right, relative priorities had to be established due to the reality of limitations in resources for noise research at all levels of government. Thus, each category was evaluated on a scale from high priority to low priority, signifying where emphasis needed to be placed. Each category was assigned one of five priority levels, from "A" (highest priority) to "D" (lowest priority). This prioritization was based on a rating and tradeoff among five evaluation factors:

- Severity of the particular health problems, as perceived by EPA, based on such available data as the number of Americans affected, and the potential severity of the insult (potential magnitude of health effects)
- Program needs of Federal, State and local environmental noise control programs within specific time frames
- Scientific recommendations of experts concerning the degree to which additional research is urgently needed

- Scientific feasibility of carrying out the needed research within a reasonable time frame, with reasonable resources
- Appropriateness of additional research activity, in the context of whether other organizations are already performing or are expected to conduct the desired research in a focused and consolidated manner.

In performing the evaluation of overall priorities among categories, each of these five factors was evaluated (as high, medium or low) and then weighted. For example, if additional research in a specific category was evaluated to be "high" in appropriateness, it meant that the needed research was not being conducted elsewhere and would not be accomplished without the commitment of new resources. However, not all factors were considered equally important. The most important considerations were the severity of the health problem and the degree to which the proposed research would meet programmatic needs of environmental noise control activities. These were weighted accordingly.

## 2.1 Overall Results of Priority Analysis

Based on these evaluation factors, the overall priorities of the noise Research Plan are given below, with short explanations of the ratings. It should be noted that although a category may be rated as low or medium in priority, pending Federal, State or local actions may require that a certain Initiative be investigated. This is explained in more depth in Chapters 4 through 9, in which specific plans for each category are presented.

| Importance | Level of Emphasis Rating | Category |
|---|---|---|
| Highest priority | A | Nonauditory Physiologic Effects |
| ↕ | B | (1) Sleep Disturbance<br>(2) Individual and Community Response |
|  | C | (1) Noise-Induced Hearing Loss<br>(2) Behavioral, Social, and Performance Effects |
| Lowest priority | D | Communication Interference |

## 2.2 Level of Emphasis A (Highest Level)

### 2.2.1 Nonauditory Physiologic Effects*

This research area is the highest priority because it has the greatest potential health implications and no other Federal agencies or other organizations are adequately researching this category.

Severity.--The potential health problem posed by nonauditory physiologic effects is very great. Noise, like other physical stressors, is capable of producing a variety of physiologic stress responses in the body. Stress has been linked to a number of chronic disorders prevalent in our society. Although there are scattered findings associating noise with a number of health problems, the best-documented relationship is the one between noise and elevated blood pressure and related cardiovascular problems. Heart disease ranks as the number one cause of death in America. Hypertension--the most likely specific effect of noise--is a demonstrated risk factor in the development of heart disorders, stroke and kidney disease. It is conservatively estimated that from 23 to 27 million Americans suffer from hypertension. For a very large proporation of these cases (90 percent), the causes are not known; yet hypertension contributes to 250,000 deaths annually in the United States. If, as some evidence suggests, there is a cause-effect relationship between noise and hypertension, the health implications of such a relationship would be widespread and serious. In addition to cardiovascular effects, other nonauditory physiologic effects of noise may be equally serious. That is why it is urgent to find out as soon as possible the extent to which such relationships exist.

---

* This category covers physiologic effects other than the physiologic effects of noise on the ear.

Program Needs.--The need for better information in this category is very great because environmental noise abatement program activities are based on the need to protect the public health and welfare. To the extent that criteria presently in use (annoyance, hearing loss, activity interference) do not take into consideration some of the most serious effects such as the potential for cardiovascular disorders, they are deficient. The planned research program should, in the near term, verify the extent to which a relationship exists between noise and physiologic health, and therefore, possibly change both the direction and importance of environmental noise abatement activities. However, it is unlikely that near-term research will be sufficient to yield the type of detailed, quantified criteria which environmental noise abatement programs ultimately require. Near-term research results showing a linkage between noise exposure and nonauditory physiologic health effects should serve as a catalyst for increased research support from other sponsoring biomedical research agencies and organizations.

Scientific Recommendations.--Health scientists from all over the world have recommended that more attention be given to nonauditory physiologic effects of noise. These recommendations are based upon the findings of research to date. The Third International Congress on Noise as a Public Health Problem (Freiburg, West Germany, 1978) pointed out the necessity for giving priority to this research. Since the previous International Congress in Dubrovnik in 1973, over 100 reports of related research studies have been published in the international literature, dealing not only with the heart and circulatory system, but also with effects of noise on vision, fetal development, biochemical constituents of the bodily system, the digestive system, the muscular system, and the nervous system.

A committee (CHABA Working Group 81) of the National Academy of Sciences has recently recommended that investigation of the relationship between noise and medically significant physiological responses be accelerated, with cardiovascular measures as the initial focus.

Moreover, a recent Workshop of cardiovascular experts at the Massachusetts Institute of Technology underscored the plausibility of the linkage between noise and cardiovascular problems, and urged that a high priority be placed on research in this area, including epidemiological research.

Scientific Feasibility.--There are some definite methodological difficulties involved in conducting research on the nonauditory physiologic effects of noise.

Understanding the ways in which noise can change the body's dynamic physiologic systems requires a serious and in-depth program of research. A coordinated program of animal, human clinical, and epidemiological research is essential. Conducting valid research in this area requires the blending of advanced acoustic measurement with sophisticated and detailed monitoring of physiological indicators in both acute and chronic noise exposure situations. For the most part, the techniques are currently available; the problem is bringing them to bear on the study of noise effects. The essential development of quantifiable dose-response criteria depends on the careful and logical accumulation of causal data. It is optimistic to think that any single study or set of studies will yield the type of data that is required. Although the problems standing in the way of good research in this category appear formidable, the challenge is not different from that faced in most areas of biomedical research. EPA sponsored research in Fiscal Years 1980 and 1981 have already improved the state of the art in methodologies for related animal studies. Replication studies using two different animal models are currently well underway in two major medical laboratories.

Appropriateness.--It is unlikely that the required research will be performed without additional action. Based on a review of research being conducted or sponsored by Federal agencies, very few relevant research efforts are currently being sponsored by other agencies, except for a joint EPA study with by the National Institute of Environmental Health Sciences, and a small prospective epidemiolgoical study initiated this past year by the National Heart, Lung and Blood Institute. Therefore, further active research in the Nonauditory Physiologic Effects Category, particularly in research concerning the cardiovascular system, will not be duplicative of other efforts and are urgently needed.

## 2.3 Level of Emphasis B

### 2.3.1 Sleep Disturbance

Severity.--Millions of Americans live in areas where the potential for nightly sleep disturbance by noise is high. Such residential sleep interference is one of the primary contributors to irritation and annoyance by neighborhood noise.

Some subjective effects of sleep disturbance that have been reported are fatigue, irritability and poor work performance. Often, a greater susceptibility to illness has been attributed to a poor night's sleep. Nevertheless, none of these suspected effects has been fully explored or measured.

Chronic sleep disturbance is a potentially severe health problem, yet little is known about the long-term effects of sleep disturbance on health, the national incidence of sleep disturbance by noise, and its effects on subsequent task performance and safety implications on the job, in traffic and in other settings.

Program Needs.--Two criteria (awakening, and sleep disturbance or changes from deeper to lighter sleep) are currently used to quantify the benefits of noise control actions. These benefits are then weighed against costs. Although adequate for Federal, State, or local regulatory purposes, the present criteria have several limitations that affect their generalizability to different noise sources, to typical sleeping conditions in the home, and to various population subgroups (the elderly, the ill, and others). Thus, there are requirements for a research effort in light of both the limitations in applicable research findings, and environmental programmatic needs to relate better the impact of sleep disturbance (including health and performance effects) to nightly noise levels that potentially interfere with sleep.

Scientific Recommendations.--In 1977 the Federal Noise Effects Research Panel recommended that considerably greater funding be applied in the sleep category, noting that funding levels had dropped since the Panel's 1975 report and that certain recommended research had received no attention. The Panel recommended that attention focus on chronic sleep interruption by noise, and on the effect of sleep interruptions on special populations such as the ill and the aged.

Similarly, experts at the 1978 International Congress on Noise as a Public Health Problem emphasized the need for noise effects researchers to determine the effects of acoustic and nonacoustic variables on sleep quality, while encouraging general sleep researchers to continue to study the effects of sleep quality on general health.

Scientific Feasibility.--As in the Nonauditory Physiological Effects category, there are a few methodological difficulties to be overcome. One of the primary methodological problems confronting scientists is the difficulty of transferring research activity from laboratory to residential settings. Nevertheless, in-the-home techniques have been pioneered in this country and similar techniques are currently in use in Europe.

Appropriateness.--The relative lack of other applicable research makes further action necessary. Over the last five years only limited sleep research has been performed by Federal agencies and these research studies have principally focused on aircraft noise.

### 2.3.2 Individual and Community Response

Severity.--It is estimated that well over 100 million Americans are exposed to noise that is perceived to be unwanted, unnecessary, objectionable, and disturbing. Noise levels that are known to cause annoyance and interference with everyday activities emanate from common sources including road traffic, aircraft, construction activity, and household products to name but a few. Thus noise in our communities today is pervasive and intrusive.

Annoyance that occurs as a result of exposure to noise is a complex psychosocial reaction. Although annoyance has as its basis the unpleasantness associated with noise and the disruption of ongoing activities, the response may ultimately lead to complaints or produce strong group reactions against certain noise sources. This type of annoyance response has not yet been experimentally identified with adverse physiologic reactions. Instead it is related to subjective feelings of irritation, being upset, and a general lack of well-being.

Nevertheless, increasing evidence of a possible association between excessive noise and stress-related health problems, such as hypertension and digestive changes, may link the annoyance or irritation that we commonly feel toward noise to the undesirable health effects that may occur. Although this link has as yet not be scientifically or experimentally established, it is not unreasonable to view our annoyance reactions as a biological protective mechanism -- a warning or symptom of unwanted health effects. For example, recent community noise surveys reveal a relationship between those persons who are highly annoyed by noise and who feel that noise may be adversely affecting their health and welfare.

Program Needs.--The category of individual and community response is most important in that individuals' subjective (annoyance) reactions to noise have in fact been the primary impetus for the establishment of Federal, State and local noise control programs throughout the United States. Moreover, quantitative information that is available with respect to community response has formed the basis for noise emission regulations, policy, and guidance promulgated at the Federal governmental level. Community noise criteria, in the form of the percentage of people expected to be highly annoyed at specific noise levels, are the primary human response criteria used in noise control policy and legislation. These criteria have predominately been developed in a number of studies of traffic and aircraft noise in an attempt to better ascertain general community or group response to noise. Although adequate in the past for Federal regulatory purposes, the generalizability of these criteria to specific sources of noise such as construction activity and railroad noise has been questioned. As the number of different noise sources that should be considered by Federal, State and local noise programs increase, it is anticipated that more specific criteria applicable to specific sources or noise settings will be needed.

Moreover, studies completed to date have not accounted for many of the acoustic and nonacoustic factors that shape our response to noise. Severe programmatic limitations exist in understanding the influence upon individual and community reactions of certain acoustic attributes typical of many noise sources found in the community. These attributes include perceived tonal components, impulsiveness, fluctuation in level, intrusiveness over background noise, and so forth. Methods do not exist that properly account for the expected increase in adverse community reactions that typically result from these factors. Moreover, the large individual differences that typically occur in annoyance responses have not been accounted for. The result has been a rather pragmatic approach to the matter of assessing community and individual response to noise. There exists no noise annoyance calculation procedure that deals satisfactorily with the many acoustic and nonacoustic variables that influence our subjective responses to sound and, accordingly, our perspectives on the quality of our life.

Cost-effective noise abatement decisions and actions are highly dependent upon the refinement of existing criteria pertaining to individual and community response, both in environments dominated by specific noise sources, and in environments with diverse noise attributes.

Scientific Recommendations.--There exists a general consensus within the scientific community on the need for further research and the direction it should take. Scientific recommendations, including those made at the 1978 International Congress on Noise, as well as those in the 1980 World Health Organization document on environmental noise criteria*, point out that while aggregate community response to noise can be reliably predicted, more work investigating the mediating factors is needed to help account for the great individual variation in response. Further, the stress-related components of response also require more investigation. In addition, as communities experience changes in their noise environment, longitudinal studies should be conducted to assess adaptation and societal changes in public reaction to noise.

---

* World Health Organization, Noise (Environmental Health Criteria 12). (Geneva, Switzerland: W.H.O., 1980).

Scientific Feasibility.--Research in this category has a high expectancy of achieving useful results because it is based on very successful, well-established techniques (attitudinal survey methodologies and psychoacoustic test procedures) that are commonly used to study subjective human reactions to noise. Improved subjective and acoustic measurement methodologies are now available.

Appropriateness.--Although other Federal agencies are active to some extent in parts of this research area, the research gaps left are sufficiently critical to require further activity. Recent Federal efforts, primarily by the National Aeronautics and Space Adminsitration, the National Bureau of Standards, and the Air Force, have been signficiant, but have focused on relatively narrow study areas, mainly aircraft noise. Information needs specific to broad environmental noise program requirements have not been fulfilled by these other research efforts.

## 2.4 Level of Emphasis C

### 2.4.1 Noise-Induced Hearing Loss

Although much additional research in noise-induced hearing loss (NIHL) is needed, feasible, and related to environmental program needs, this Research Plan places only medium emphasis on the need for more research, largely because of the planned research programs of other Federal agencies.

Severity.—Noise-induced hearing loss is the most widespread occupational health problem in the United States, and there is evidence that additional noise exposure from environmental sources exacerbates the problem. Of the estimated 20 to 25 million people in the United States exposed to levels of noise sufficient to cause irreversible damage to their hearing, 15 million are estimated to be workers exposed to noise on the job.

It is particularly important to consider the problem of workers whose workplace exposures are augmented by off-the-job exposures. Other potentially hazardous exposures occur in transit, in using appliances and power tools at home, and in common recreational activities. Preliminary information also suggests that people in comparatively low noise work environments, such as office workers and homemakers, are exposed to 24-hour noise exposure levels which may place some of them at higher risk to hearing damage.

Impulse noise is another particularly severe problem in the occupational setting which has not been adequately addressed. It is estimated that over 2.7 million workers are exposed to impulse noise and are not covered adequately by present damage risk criteria.

It is estimated that as many as 29 million Americans suffer from a handicapping hearing loss. Persons suffering from noise-induced hearing loss often report other health disturbances as well. They are also frequently the victims of tinnitus (ringing in the ears), lowered auditory discomfort thresholds and other annoying side effects. Impaired hearing can be socially debilitating. Persons with NIHL often speak of difficulty in understanding communication, withdrawal from social contacts, embarrassment, frustration and isolation. Noise-induced hearing loss greatly affects the lives of millions of individuals. It is a difficult problem since the process is gradual and insidious and may not be apparent until a considerable amount of hearing is lost.

Program Needs.--Although scientifically acceptable damage risk criteria exist, better defined hearing loss criteria are required to support the full array of environmental noise control programs. Federal, State and local governments need to know the extent of the hearing loss problem caused by noise exposures outside of the workplace in order to develop responsive policies to protect the population at risk. The probability that a person will develop a noise-induced hearing loss depends on the individual's total exposure from all noises at work, home, and in the community. A determination of those sources and each source's contribution to an individual's risk of hearing loss should provide added direction to governmental regulatory programs and the development of appropriate noise control actions.

Scientific Recommendations.--There is a widespread consensus on the need for further research on the key segments of the NIHL research category, as characterized by conclusions reached at the 1978 International Congress on Noise, a recent NIH workshop on noise research*, the Federal Noise Effects Panel Report, and the 1980 World Health Organization (WHO) report. As recommended by these groups, future research should concentrate on some of the less well defined aspects of the problem such as the question of hearing loss caused by specific environmental sources, the effects of intermittent and impulsive noise, and the question of determining risk to susceptible populations such as children. These areas have in the past received a low level of funding and should be addressed in future research.

Scientific Feasibility.--The feasibility of ongoing and planned NIHL research is generally high. It is solidly based on research performed over the last 30 years. The development of new sophisticated personal monitoring instrumentation, clinical methodologies, and microscopic assessment techniques makes research possible today that could not have been undertaken several years ago.

---

*National Institute of Neurological and Communicative Disorders and Stroke. Workshop on Effects of Noise on Hearing: Research Directions and Designs, June 1978.

However, in the future, certain avenues of research may be limited. For one, workers included in samples for scientific study should not be exposed to high noise levels which may jeopardize their hearing. Effective enforcement and compliance with Federal workplace noise provisions may make it difficult to identify workers for hearing loss field studies. If workers exposed to high levels of noise were found, it would be irresponsible not to take necessary actions to provide them with adequate hearing protection. Similarly, many research institutions are finding it difficult to obtain approval for human subject research under high noise exposure conditions.

Appropriateness.--Over the last three years, more than eleven different Federal agencies have funded noise-induced hearing loss and hearing conservation research studies at an average total funding level of over $3 million per year. However, very few of the relevant research studies funded under this category are investigating hearing loss due to environmental noise exposures and noise-induced hearing related problems of children. Thus, although there is continuing interest on the part of other agencies in funding NIHL research, there is a need for a focused program of additional, applied research in areas not presently being adequately covered.

### 2.4.2 Behavioral, Social and Performance Effects

The category of behavioral, social, and performance effects of noise is an extremely broad category, whose effects are often subtle, complex, and indirect, and usually mediated by nonacoustic factors.

Severity.--Although the scientific literature contains many potentially important findings, not enough information exists at this time to allow proper consideration of the severity of noise effects. Enough is known, however, to identify those areas that are important and most in need of research. There are some definite indications of antisocial and aggressive behavior resulting at least indirectly from noise, performance decrements due to noise, learning disabilities attributed to, or aggravated by noise, and stress-related psychological responses that may be due in part to noise. Some very important questions exist concerning the way in which individuals adapt to and cope with noise, and how the performance, productivity and social and personal adjustment of adults as well as children may be impaired by noise.

Information is particularly needed on how noise affects the development of language and cognitive skills in children. Some of the most pervasive effects of noise fall within this category. These are important questions because they pertain to how noise interferes with personal, mental and social functioning and makes the accomplishment of important goals more difficult.

Program Needs.--The adverse behavioral, social and performance effects of noise are clearly relevant to environmental noise control program requirements. At present, there are no criteria for any of the effects that noise may have on behavior and/or performance. To the extent that further research enables effects to be quantified in the form of criteria, they should be included in assessments made in support of Federal, State and local noise control activities. For example, definitive information concerning how noise affects the acquisition of language and other cognitive skills may necessitate that special consideration to be given to noise around schools and residential environments, and to the modification of existing communciation interference criteria. Information on behavioral and social problems associated with specific noise exposure in certain settings would have a direct application to environmental noise control programs. This category of effects may be especially important where levels of exposure are only moderately high or where contextual factors characteristic of the exposure situation appear important.

Scientific Recommendations.--Recent international scientific congresses on noise have emphasized both the potential significance and the extreme complexity of noise problems in this research area. One of the general areas that has been identified for future research is in the determination of the sociological effects of noise in relation to the quality of life. Other gaps in the scientific literature have been identified and a more realistic posture has been taken toward the level of sophistication required to attack these multivariate research questions.

Scientific Feasibility.--The complexity and subtleness of noise effects in this category necessitate the use of sophisticated and elaborate research designs and detailed, multivariate techniques for data analysis. The fact that noise seldom occurs alone in natural settings requires that an effort be made to ensure that research outcomes are attributable to noise. In spite of these difficulties, a number of behavioral science and sociological methodologies are available for carrying out a program of research and systematic replication which could be expected to yield results of use to environmental noise abatement activites.

Appropriateness.--Because of the relative lack of research activity at present, new studies should be initiated if this important area is to be investigated to any signficant degree. Even the ongoing task performance research is not directly applicable to the environments of concern to Federal, State and local environmental officials. The relatively small amount of ongoing research on the effects of noise on children is exploratory in nature and should be used in planning more focused research in this important area.

## 2.5 Level of Emphasis D

### 2.5.1 Communication Interference

Severity.--In terms of severity of the problem, everyday experience shows that almost all Americans are exposed to noise at levels sufficient to interfere severely with their activities at home (including conversations and listening to TV, radio, or recorded music), in transit, and at their workplace. Interference with speech communication is more than an annoyance. It represents a reduction in efficiency, and in some circumstances a real threat to safety resulting from messages being missed or misunderstood.

Program Needs.--Investigation of communciation interference is highly relevant to environmental noise program needs because many of the existing noise regulations are based on well quantified criteria for speech interference. While these criteria are adequate for Federal, State and local regulatory purposes, they may need refinement to ensure their suitability in nonsteady-state background noise conditions and for listeners other than normal hearing, native adults.

Scientific Recommendations.--There is consensus on the directions for continued research including: extension of the generalizability of research based on communication systems to other situations; increased emphasis on quality of communication; requirements for communication in fluctuating noise situations; and the speech communication requirements of special groups such as the very young and hearing-impaired listeners.

Scientific Feasibility.--As one of the older and better established disciplines, communication interference is well suited for further study with the well developed methodologies available.

Appropriateness.--Previous research and the work currently underway may minimize the need for priority emphasis, with a few exceptions. There are a few, well-defined topical areas not presently being adequately covered. These include development of refined criteria for the effects on special groups such as children, special effects in teaching and learning activities, and secondary effects of disrupted communciation on safety and task performance. One of the major areas of concern relates to the communicative problems of the hearing impaired. Although there are as many as 29 million Americans with impaired hearing, their communicative problems are not as well understood as they should be.

## 3. EPA'S RESEARCH PLAN IN DETAIL (INTRODUCTION)

### 3.1 Definition of Long-Range Objectives

As an initial step in developing a Research Plan, it was necessary to define long-term objectives for each of the categories of health effects research. This was done in Chapter 2, where long-term objectives were defined as broadly as possible in the light of Federal, State and local programmatic needs, so that if they were fulfilled, environmental noise abatement programs would have an adequate "health and welfare" information base. This information base is needed to support future activities that will effectively and efficiently minimize adverse noise in our environment at the lowest cost possible and with the least disruption to our lives. These long-term objectives will be used for purposes of reference as general targets.

### 3.2 Definition of Short-Term Objectives

In order to make the Plan operational in the short term (Fiscal Years 1981-85), it is necessary to develop a set of short-term research objectives. The short-term research objectives are those which have been selected as appropriate for initial action within five years. The short-term objectives, therefore, represent a set of limited but important milestones in pursuit of the identified long-term objectives.

To date, EPA has sponsored a substantial amount of research during the Fiscal Year 1981-82 period in accordance with this Research Plan. The present updated version of the Plan will describe the progress of EPA-sponsored research to date (Fiscal Year 1981), will forecast research results expected through the end of Fiscal Year 1982, and will outline the specific Research Initiatives that remain to be undertaken in pursuit of the identified short-term objectives.

## 3.3 Definition of Research Initiatives

Corresponding to each short-term objective in the Plan are one or more Research Initiatives. Each Research Initiative is conceived as a particular line of inquiry in pursuit of a specific, identified objective. Research Initiatives should be time-phased, both because of resource constraints and because of the intent that outputs of some Initiatives will act as prerequisites necessary to initiate others. Further, a given Research Initiative should not be thought of as a "project" or "program." In many cases a given Research Initiative will consist of a number of components which are frequently supported by one or more projects in a time-phased manner. Furthermore, a single research project may support one or more Research Initiatives.

Table 3-1 contains a list of those Research Initiatives most important to the support of environmental noise programs, and which should be undertaken in the near-term period, i.e., within the first five years. The Initiatives are not at the present time being supported with adequate research efforts by other Federal agencies or research organizations. In some cases, no related research at all is being funded.

Table 3-2 identifies other important Research Initiatives, of a secondary priority, which should be undertaken in the near term

## TABLE 3-1. PRIORITY RESEARCH INITIATIVES INCLUDED IN THIS PLAN

| | | |
|---|---|---|
| NONAUDITORY PHYSIOLOGIC EFFECTS | I. | Animal experimental studies on the relationship between noise, elevated blood pressure and other cardiovascular system effects |
| | II. | Epidemiolgoic studies on the relationships between long-term noise exposure and adverse cardiovascular effects |
| | III. | Human studies and clinical investigations of cardiovascular and neuroendocrine responses to noise |
| SLEEP DISTURBANCE | I. | Relationship between field and laboratory data on sleep disturbance by noise |
| | II. | Health consequences of noise-disturbed sleep |
| | III. | Acoustic parameters related to sleep disturbance |
| | IV. | Susceptibility of sensitive populations to sleep disturbance by noise |
| | V. | Adaptation to sleep disturbance by.noise |
| COMMUNITY AND INDIVIDUAL RESPONSE | I. | Determination of the magnitude of community and individual response attributable to specific sources of noise |
| | II. | Determination of the relationship between specific acoustic attributes and the magnitude of individual/group response to noise |
| NOISE-INDUCED HEARING LOSS (NIHL) | I. | Determination of the prevalence of NIHL in the United States and the contribution of sociocusis (nonoccupational exposure, presbycusis (aging), and occupational exposures. |
| | II. | Establishment of parameters of individual sensitivity to NIHL |
| | III. | Refinement of criteria for low-level noise exposures |
| | IV. | Determination of social and economic impacts and other consequences of NIHL |
| BEHAVIORAL, SOCIAL AND PERFORMANCE EFFECTS | I. | Effects of noise on cognitive and social development |
| | II. | Behavioral and social adjustment to noise |

## TABLE 3-2

## SECONDARY RESEARCH INITIATIVES: OTHER POTENTIALLY USEFUL RESEARCH INITIATIVES (NOT DISCUSSED IN DETAIL IN THIS PLAN)

| | | |
|---|---|---|
| NONAUDITORY PHYSIOLOGIC EFFECTS | I. | Laboratory and field studies of other medically significant responses to noise |
| | II. | Descriptive and correlational studies of the relationship of noise to health symptoms, complaints and behaviors |
| | III. | Impact of living or working in high-noise environments |
| | IV. | Effects on of noise on physical growth, development and general health of children |
| | V. | Interaction of noise with other stressors and environmental hazards |
| COMMUNITY AND INDIVIDUAL RESPONSE | I. | Identification and quantification of nonacoustic determinants of community and individual response to noise |
| | II. | Determination of susceptible population subgroups |
| NOISE-INDUCED HEARING LOSS | I. | The effects of voluntary and less aversive noise exposures on the hearing sensitivity of an individual |
| BEHAVIORAL, SOCIAL AND PERFORMANCE EFFECTS | I. | The effects of noise on social and behavioral pathology |
| | II. | Individual differences in sensitivity to noise |
| | III. | The relationship between noise exposure and worker productivity |
| | IV. | The role of various acoustic and nonacoustic factors on task performance |
| | V. | Interaction of noise with other stressors |
| COMMUNICATIONS INTERFERENCE | I. | Criteria for relaxed conversation in different environments |
| | II. | Speech intelligibility for special groups (e.g., the hearing-impaired) |
| | III. | Effects of time varying noise on speech intelligibility |
| | IV. | Communication interference effects in high noise work and traffic environments |

if adequate progress is to be made in meeting the requirements and objectives of the priority Initiatives. The secondary Initiatives should not be construed as being of reduced importance. These Initiatives are integral to the national noise control effort. The only reason they are being presented as secondary priorities is that real limitations in existing research funds require that primary emphasis be placed in supporting the most highly prioritized Research Initiatives. Once funding of these Research Initiatives is underway, work should be started at once to fund the broader set of secondary Research Initiatives.

The reader should note that certain tradeoffs had to be made in selecting the prioritized Research Initiatives in each category. It was decided that it would be more reasonable to select a limited number of Initiatives in order to assure that:

- The identified research could be funded even with typical budget constraints. In general, the cost of the types of the required biomedical animal, human clinical and epidemiologic research projects in this Plan are quite high.
- The research results would be available in the near term to provide guidance and refined criteria in support of Federal, State and local environmental noise control activities.

After the initial thrust in cardiovascular research is completed and detailed results are available, it is assumed that there would be a shift in the lead funding role to the National Institutes of Health (NIH), and, therefore, an expansion of the proposed research effort in line with the described long-term Nonauditory Physiologic Effects research objectives.

## 3.4 Concept of Evolution in Research

Underlying the approach taken by EPA in developing the Plan is the fact that the research categories for which long-term objectives have been set differ from each other in at least one important respect: the maturity of research activity in the category. For long-established categories, information is organized around well defined and generally accepted concepts and methodologies. Furthermore, there is a group of recognized specialists pursuing more advanced questions such as the refinement of criteria or the investigation of the specific health risk to special populations. Other categories, which only recently have begun to be recognized, are still developing conceptually, and frequently need to involve specialists from unrelated fields organized in a cross-disciplinary, biomedical research effort. In this case the problem may not be well enough defined, the results are less consistent, the methodological problems are greater, and the probability of failure is higher than for research in the more established categories.

For any of the categories of research presented in Chapters 4-9, a logical and scientifically developmental sequence of research activity can be suggested. This sequence is typically followed in the development of quantified dose-response relationships, the determination of health effects risk, and ultimately, the development of refined human response criteria. These are steps in an empirical research process. This sequence is shown in Table 3-3. Thus, certain types of research are the building blocks on which progress in the more advanced topics depends. The kinds of results that can reasonably be expected

## TABLE 3-3

## RESEARCH CONTINUUM IN THE DEVELOPMENT AND REFINEMENT OF HEALTH EFFECTS CRITERIA

1. Demonstrate the existence of an association
2. Demonstrate a basic cause-effect relationship directly attributable to noise
3. Investigate underlying mechanisms and physiologic bases of the effect
4. Improve the cause-effect relationship through the investigation of intervening factors
    - A. Acoustic factors
    - B. Nonacoustic factors
5. Establish dose-response relationships, determine risk, and develop quantified human response criteria
6. Refine criteria based upon susceptible populations and special considerations

from new research depend in part on where the research category falls on this research developmental continuum.

In some areas of research where the health effect is critical, research may be undertaken out of sequence. The attempt to develop criteria in the shortest possible time often results in wasteful research, large funding expenditures, many unanswered questions, and continued debate over the implications of the results. In introducing the Research Plan for each objective, therefore, an attempt has been made to place the current status of research in that category somewhere on this developmental continuum. For example, while research in the Noise-Induced Hearing Loss and Communication Interference categories are relatively highly developed specialities, research in the Nonauditory Physiologic Effects category belongs at the other end of the spectrum. That is, research proposed in the category of Noise-Induced Hearing Loss will lead to the refinement of criteria, whereas research being proposed in the category of Nonauditory Physiologic Effects will attempt first to demonstrate a basic cause-effect relationship directly related to noise exposure.

In the Research Continuum Table included in each chapter of this Plan, the status of research in each category has been evaluated as either "Adequate," "Marginal" or "Inadequate." These labels denote adequacy with respect to reaching the ultimate objective of fully refined criteria for each noise effect category. However, these labels do not reflect a judgment of adequacy for Federal, State or local regulatory purposes, although such regulatory analyses employ the best available health and welfare information. These Tables are included to allow the reader to compare the status of knowledge in a comparative manner, across the different noise-related health effects categories.

## 3.5 Contents of the Research Plan for Each Category

The total Research Plan consists of a separate Plan for each of the six research categories. A number of Research Initiatives are proposed in each category. Each Plan will consist of the items shown in Table 3-4.

## 3.6 Nature and Direction of Research Findings

The Research Initiatives suggested for study within this Plan are proposed with the aim of deriving findings that will lead toward criteria development within each of the research categories. However, there exist no guarantees on the results of the specific studies that should be undertaken. Biomedical research is by nature a continual learning process. Each step of investigation at times necessitates redefinition of new directions. This may involve the replication of previous studies or the abandonment of certain projects, depending on the results in each stage of the research process.

## 3.7 Guidance and Monitoring

A Review Panel/Advisory Group should be established to provide guidance and direction to, and periodic review of the total research program outlined in this Plan. At present, EPA coordinates two Interagency Panels: (1) Federal Noise Effects Research Panel,

## TABLE 3-4. ITEMS INCLUDED IN THE PLAN FOR EACH RESEARCH CATEGORY

1. Rationale for Selecting Specific Research Initiatives--For funding over the Five Year Period.

   - What is Known.--Status of research in the category.

   - What is Not Known.--Research that needs to be conducted to fill in important deficiencies in data and improve understanding of specific health effects.

   - Priorities.--For Health Effects research based on public health and welfare needs in support of Federal, State and local noise control activities.

   - Current Research Activities.--Ongoing research projects of EPA and other Federal agencies.

   - Position on the Research Continuum.--Status of research in relation to the development of refined health effects criteria.

   - List of Priority Research Initiatives Necessary to Better Suport Public Health and Welfare Needs.--Identification of specific lines of inquiry for near-term pursuit of category objectives.

2. Detailed Descriptions of the Research Initiatives--Each description includes:

2.1 Priority Research Initiatives

   - Description and Basic Considerations

   - Relation to Other Ongoing Research.--Federal and private.

   - Expected Results.--How the results will be used upon completion of the Initiative.

   - Results to Date.--If EPA has started projects.

2.2 Secondary Research Initiatives--Recommended for support by other agencies and research organizations once the "priority" Initiatives receive adequate attention.

3. Sequencing of the Research Initiatives.--A specific time phasing of research is needed because the outputs of some Initiatives function as prerequisites necessary to initiate others. Sequencing recommendations will only be made in the Nonauditory Physiologic Effects Research category due to the complexity of the proposed research effort and the fact that only minimal research has been done in this area.

and (2) the Health Effects Research Advisory Group, which are both comprised of representatives of the various Federal agencies with research-related interests and expertise in noise effects.

The Health Effects Research Advisory Group should be supplanted by a group comprised of representatives from both the academic research community and from the relevant Federal agencies. The membership of this group should not be limited to bioacoustical scientists, but should be representative of the full array of expertise that would be required to conduct the interdisciplinary biomedical research Initiatives identified in the present Plan. At a minimum, the specialties represented should include: cardiovascular and stress physiology, cardiovascular medicine, biostatistics and epidemiology, behavioral science, psychoacoustics, bioacoustics and physical acoustics.

This group should review study protocols and interim and final results, discuss and propose necessary changes to the Research Plan, and provide a forum for the general discussion of related issues and problems. The group should function, to the extent possible, in a fashion that is independent of established systems for the technical monitoring of grants and contracts for the peer review of proposals. Once this group is established and becomes operational, it should as well be used by other Federal agencies as a forum to provide guidance and direction in planning their respective research efforts. Thus, this group has great potential in becoming a national forum for coordinating, planning, reviewing, and exchanging and disseminating the research results and plans of the total Federal noise-related health effects research effort.

The Federal research effort would greatly benefit from joint planning exercises between different agencies and organizations. The type of research proposed herein is multidisciplinary in nature, requiring expertise in a number of biomedical and bioacoustical areas. The participation of more than one Federal agency in the proposed research effort is necessary to insure more effective research design, monitoring and review, and to provide research outcomes with programmatic relevance to more than one agency. Biomedical research is very expensive to conduct. Where feasible, costs should be shared in order to avoid duplication and superficiality. In order to make significant progress in a timely fashion, a concerted program of interagency research is appropriate.

It is recommended that the findings obtained in studies described in this Research Plan be presented at scientific meetings and published in refereed journals. Furthermore, open scientific symposia and workshops should be scheduled on a regular basis. These activities should serve to maximize critical review of the research programs and also serve to stimulate the scientific community.

# 4. RESEARCH PLAN FOR NONAUDITORY PHYSIOLOGIC EFFECTS

# TABLE OF CONTENTS

Contents Page

4.1 Rationale for Selecting Specific Research Initiatives Over the Five-Year Period 4-1

  4.1.1 What is Known 4-1

  4.1.2 What is Not Known 4-3

  4.1.3 Priorities 4-4

  4.1.4 Current Research Activities 4-6

  4.1.5 Position on the Research Continuum 4-8

  4.1.6 List of Priority Research Initiatives Necessary to Better Support Public Health and Welfare Needs 4-8

4.2 Detailed Description of the Research Initiatives 4-10

  4.2.1 Priority Research Initiatives 4-10

    I. Animal Experimental Studies on the Relationship Between Noise, Elevated Blood Pressure and Other Cardiovascular System Effects 4-10

    II. Epidemiologic Studies on the Relationship Between Long-Term Noise Exposure and Adverse Cardiovascular Effects 4-13

    III. Human Studies and Clinical Investigations of Cardiovascular and Neuroendocrine Responses to Noise 4-19

  4.2.2 Secondary Research Initiatives 4-22

    IV. Nonauditory Physiologic Effects Initiatives Other Than Cardiovascular Effects 4-22

4.3 Sequencing of Research Initiatives 4-25

# 4. RESEARCH PLAN FOR NONAUDITORY PHYSIOLOGIC EFFECTS*

## 4.1 Rationale for Selecting Specific Research Initiatives

The long-term objective of nonauditory physiologic effects research is to determine the physiologic effects of noise on bodily systems and on general health, with special emphasis on hypertension and other cardiovascular effects.

### 4.1.1 What is Known

Studies have shown that noise can act as a biologic stressor. Nonauditory physiologic stress reactions, such as transient changes in blood pressure, heart rate and respiration, alterations in hormonal levels and gastrointestinal motility, and measurable changes in skin resistance and muscle potentials have been documented for noise exposures typical in level to those encountered in the human environment. The hormonal changes and other effects produced in animals and humans to noise appear to be similar to those elicited by other challenging and demanding influences in the physical and psychological environment.

Laboratory research with rodents has yielded a variety of both transient and enduring morphologic, hormonal and metabolic responses to noise. The generalizability of the results of these studies is severely restricted due to the proclivity for convulsive behavior ("audiogenic seizures") among rodents and to the fact that the auditory sensitivities of rodents differ considerably from those of humans.

---

* For a more detailed discussion of reguired cardiovascular research with complete finding and timing figures, see "Detailed Cardiovascular Research Plan," EPA, Sept. 1981.

There is evidence that the fetus can be affected by noise stimuli, either directly or through changes induced in the system of the mother. Only a very small amount of animal and human work has been done in this area, but there are some preliminary data suggesting stress-related adverse effects such as alterations in hormonal and biochemical activity, reduced birth weights, and behavioral and neurological effects.

The consequences of long-term noise exposure on general health status have been examined in several correlational field studies. Overall, these studies have provided a complex pattern of results. There are data indicating that chronic noise exposure is associated with a number of common health problems and complaints. Not atypical of field research, many of these studies are subject to criticism on methodological grounds. The major problem in this type of research is determining whether noise *per se* is the cause of the adverse effects.

By far, the largest body of research exists on the relationship between long-term noise exposure and hypertension and other cardiovascular problems. Approximately 40 cross-sectional, retrospective epidemiologic studies have been conducted, mostly in Eastern European countries. Research in at least 11 different nations and in at least 18 different industries suggests increased cardiovascular morbidity as a function of long-term noise exposure. Hypertension appears to be the most prevalent concomitant of noise exposure in these studies. Although it is difficult, for a number of reasons, to adequately evaluate these studies, the apparent magnitude and consistency of these findings cannot be ignored.

In addition, two recent studies, one in the United States and one in Germany, have reported elevated blood pressure among children living and/or attending school in high noise areas. These studies are particularly noteworthy in determining the significance of environmental factors in the development of hypertension.

Recent laboratory research in this country, using a more appropriate animal model, the Rhesus monkey, has shown that as little as several months exposure to environmental noise levels can produce significant and sustained elevations in blood pressure of approximately 30 percent. These observed elevations would be considered hypertensive in human patients and would be reason for medical concern. Furthermore, even a month after the noise was turned off, the animals' blood pressures did not return to pre-exposure levels, suggesting that recovery, if it occurs, will take some time. This type of controlled investigation, where noise is the only stressor present, parallels past epidemiologic research, and suggests the importance and the promise of study in this area of noise effects research.

### 4.1.2 What is Not Known

Although it is known that noise acts as a stressor, it is not known with certainty whether prolonged exposure results in cumulative pathology. Whereas the organism is often capable of adapting to noise at the conscious, behavioral level, elevations in blood pressure and other physiologic changes appear not to adapt. What is the overall medical significance of these physiologic effects? Precise cause-effect relationships need to be drawn between noise and medically significant physiologic responses such as blood pressure, and between noise and the so-called stress diseases or diseases of adaptation.

Information is lacking on the mechanisms underlying noise related changes and the extent to which noise operates in a similar fashion to other better understood stressors.

Quantitative data are virtually nonexistent concerning the role played by the various physical parameters of noise, its level, frequency spectrum, temporal pattern,and duration. The extent to which nonacoustic factors, or the context in which the noise occurs, mediate the stress effects of noise is not known and should also be specified. This is the type of information necessary to develop quantitative criteria in support of noise control activities.

Attention should be given to identifying those segments of the population that might be particularly susceptible to these effects, for example, children and the elderly. Individual differences should be investigated. Information pertaining to the extent to which chronic noise exposures might exacerbate pre-existing health problems such as hypertension is not available.

### 4.1.3 Priorities

The most urgent health and welfare research need, in support of Federal, State and local noise control requirements, is to verify as soon as possible the extent to which a cause-effect relationship exists between noise and stress-related diseases such as cardiovascular disease, on the grounds that the scope of the potential public health problem is great. Noise is probably the most pervasive pollutant in both the occupational and nonoccupational environment, and in recognition of the potential health problem, special emphasis should be placed on conducting research on the nonauditory physiologic effects of noise. Adequate and quantitative health effects information is the basis of any type of noise control program or activity.

Statistical associations have been demonstrated between noise and cardiovascular problems, but their ultimate significance awaits further, more sophisticated research aimed at establishing causality. A combination of animal, human clinical and epidemiological research is required. Information must be obtained on the role of various acoustic and nonacoustic variables, and on the susceptibility of various subpopulations to noise-related cardiovascular effects. This type of information is required in order to develop quantitative dose-response criteria. Although a fairly extensive and costly program of research is required, the costs of ignorance are potentially very great.

It must be recognized that little is known about any of the possible nonauditory physiologic effects of noise, and that the health consequences are potentially great for all of these effects. However, for the following reasons, the recommendation is made to concentrate primarily on cardiovascular effects research (since not all areas can be researched in depth simultaneously):

(1) Cardiovascular effects are relatively well documented;

(2) Cardiovascular effects research is feasible scientifically;

(3) Cardiovascular effects are potentially linked to a serious and widespread health problem.

### 4.1.4 Current Research Activities

EPA has had more than four years experience sponsoring nonauditory physiologic research. The major EPA effort has been an investigation of the relationship of noise to sustained elevations in blood pressure using a primate model. This study is being conducted at the University of Miami Medical School. Findings to date have revealed sustained blood pressure elevations as a function of exposure to environmental noise levels. A second program of primate research has recently been initiated at the Johns Hopkins Medical School with support from EPA. Human experimental research has also been initiated in a second project at Johns Hopkins. Research on the health effects of chronic sleep disruption by noise, being conducted at Stanford University Medical School with support from EPA, should also yield information relevant to understanding the nonauditory health effects of noise. EPA has also sponsored an epidemiology feasibility study to be completed in 1981. This study will lay the foundation for subsequent research. It will provide an objective assessment of the foreign epidemiological literature, the analysis of key sets of foreign epidemiological data, and an evaluation of various epidemiologic approaches.

Since 1980, EPA has been obtaining descriptive data from the National Health and Nutrition Examination Surveys on the qualitative relationship between health status and indices related to noise exposure (see Chapter 7, Section 7.2.1,I, for the corresponding Initiative).

Other Federal agencies have funded only a small amount of related research. The following studies represent recent and ongoing efforts:

- In the cardiovascular effects category, an experimental study sponsored by the Veterans Administration examined the effects of stress-producing, unpredictable noise on groups of men displaying the coronary prone personality type.
- An ongoing NIH/NIEHS project is looking at several physiologic effects of noise in rodents, such as teratogenic, hormonal and cardiovascular effects.
- The National Institute of Child Health and Human Development examined the effects of high noise levels caused by aircraft noise on the physical growth and development of children.
- A study supported by the National Science Foundation and NIEHS included an investigation of the blood pressures of children living near a large airport.
- A recently funded NIH/NHLBI cross-sectional epidemiologic study is addressing the relationship between long-term industrial noise exposure and elevated blood pressure.
- Two studies being conducted by the U.S. Navy should provide some data on health status and physiologic

response as a function of high level noise exposure in simulated and actual naval environments.

- A NIH/NHLBI-sponsored experimental study investigated autonomic responsivity to various stressors including noise in adolescents with elevated blood pressure.

### 4.1.5 Position on the Research Continuum

As can be seen in Table 4-1, the present status of research in the nonauditory physiologic effects category must be considered almost wholly inadequate for the development of human risk criteria. It is only in the cardiovascular effects area that a reasonable amount of associative data exists.

### 4.1.6 List of Priority Research Initiatives Necessary to Better Support Public Health and Welfare Needs

After reviewing the status of nonauditory physiologic effects research, environmental noise program needs and priorities, and the planned research activities of the relevant Federal agencies, the following Research Initiatives are recommended. They are not listed in order of priority.

I. Animal experimental studies on the relationship between noise, elevated blood pressure and other cardiovascular system effects

II. Epidemiologic studies on the relationships between long-term noise exposure and adverse cardiovascular effects

III. Human studies and clinical investigations of cardiovascular and neuroendocrine responses to noise

TABLE 4-1

## POSITION ON THE RESEARCH CONTINUUM - NONAUDITORY PHYSIOLOGIC EFFECTS

| Research Continuum | Current State of Knowledge | | |
|---|---|---|---|
| | Adequate | Marginal | Inadequate |
| 1. Demonstrate existence of an association | | X* | |
| 2. Demonstrate basic cause-effect relationship | | | |
| A. Animals | | | X** |
| B. Humans | | | X* |
| 3. Investigate physiologic mechanisms | | | X** |
| 4. Investigate intervening factors. Improve cause-effect relationship | | | |
| A. Acoustic | | | X |
| B. Nonacoustic | | | X |
| 5. Quantify dose-response relationship | | | X |
| 6. Refinement and special populations | | | X |

---

* Foreign epidemiological research suggests a statistical association between noise and hypertension and other cardiovascular problems. Some experimental primate research also shows adverse effects on the blood pressure.

** EPA is supporting ongoing research (FY 1980-82) which involves the examination of physiologic dynamics and causal mechanisms.

## 4.2 Detailed Descriptions of the Research Initiatives

### 4.2.1 Priority Research Initiatives

### I. Animal experimental studies on the relationship between noise, elevated blood pressure and other cardiovascular system effects.

Description and Basic Considerations.--The purposes of this Initiative are to: assess under controlled conditions the causal relationship between noise exposure and selected medically significant physiologic responses, particularly elevations in blood pressure; investigate the associated pathophysiology; and begin to develop quantitative dose-response relationships for selected effects.

The nonhuman primate is the animal of choice. Animal research with an appropriate model would permit: detailed specification of acoustic parameters, sophisticated and continuous monitoring of physiological activity, control of extraneous variables, and investigation of underlying mechanisms. There are three components under this Initiative.

#### Component I. Preliminary Investigations and Methodological Refinements.

Through 1980, the purpose of the University of Miami project has been to assess the feasibility of chronic exposure work using nonhuman primates, and to determine whether exposures to environmental noise levels produce sustained alterations in blood pressure and heart rate. Having accomplished these goals, this project has been expanded to provide necessary replications of the rather dramatic findings of the study, and to begin to examine the cardiovascular dynamics involved, and associated biochemical changes.

Expected Results.--By the end of Component I, a substantial body of animal data will have been compiled examining the relationship between noise exposure and alterations in blood pressure and other cardiovascular parameters. The physiological and biochemical mechanisms and processes involved in these effects should be better understood. Sophisticated and streamlined experimental paradigms using the most appropriate primate species should also be available at this juncture.

Results to Date.--Results from the first two sets of animals showed sustained elevations in blood pressure ranging between 20 to 30 percent for 6- to 9-month daily exposures to everyday and industrial noise episodes. The rather significant findings of sustained blood pressure elevations that were obtained in the first phase of the University of Miami study have been replicated in phase II. Detailed stress hormone and blood chemistry data will be forthcoming. Phase III of this program is underway examining the cardiovascular dynamics of the noise-related blood pressure elevations.

A second, independent program of research has been initiated at the Johns Hopkins University Medical School using baboons. The purposes of this project are to provide a systematic replication of the Miami findings, and to begin to investigate the role of various acoustic and nonacoustic factors. Work will also be started on the interaction of noise with other cardiovascular risk factors.

Important information should be forthcoming from both of these studies toward determining the most suitable experimental paradigms, exposure duration, etc.

Component II. Investigations of acoustic and nonacoustic factors.

The second Component of animal experimental studies should begin to focus on the development of quantitative dose-response criteria. Very detailed work should be done on the relationship between various acoustic parameters and cardiovascular effects. Examples of parameters to be studied include noise level, frequency content, duration and temporal pattern (e.g., intermittency).

This research should also examine the extent to which the effects are mediated by various nonacoustic factors. Interest here is with the context in which the noise occurs. Variables such as the "aversiveness" and "controllability" of the noise should be manipulated.

Expected Results.--These parametric studies will begin to provide the type of information necessary to derive tentative dose-response relationships appropriate to the animal models. Data will be available on how much noise and what kind of noise is associated with how much effect. Information should also be obtained on the extent to which nonacoustic factors influence the relationship.

Results to Date.--The Johns Hopkins study discussed above should begin to provide some preliminary data on the role of various acoustic factors. Subsequent to the replication study, an attempt should be made to vary the acoustical aspects of the industrial noise segment of the 24-hour noise exposure sequence used in the Miami study.

Component III. Investigations of differences in susceptibility.

In the third Component of animal experimental studies, attention should be directed to the determination of individual differences in susceptibility to the cardiovascular effects of noise. Work should proceed using various kinds of animals: animals selectively bred for hypertension; animals whose systems have been compromised through surgical intervention, the infusion of hormones, or through pharmacological means; animals displaying other cardiovascular risk factors; animals preconditioned to be hyper-reactive to noise and other stressors; and older animals, young animals and infants.

Expected Results.--This research should attempt to determine whether there are certain factors which predispose or place the organism at greater risk for cardiovascular effects, and whether noise exacerbates pre-existing health conditions.

Results to Date.--In the later stages of the Johns Hopkins primate study, experiments will be directed at studying the interaction of noise with salt intake as well as the interaction of noise with pre-existing blood pressure level. These studies will begin to investigate some of the factors which have been implicated in the development of hypertension and cardiovascular disease.

## II. Epidemiologic studies on the relationship between long-term noise exposure and adverse cardiovascular effects

Description and Basic Considerations.--The purposes of these studies are: to provide valid epidemiologic data on the relationship of long-term noise exposure and adverse cardiovascular effects, particularly hypertension; to determine the extent to which a causal relationship exists between noise and cardiovascular disease; and to obtain data useful in deriving criteria for detecting the effects of noise on hypertension and cardiovascular disease. There are three components within this Initiative.

Component I. Retrospective analysis.

The logical first step is to demonstrate the existence of an association by providing a more systematic and careful study of the existing epidemiologic findings. Next, taking advantage of an appropriate study population or existing data base, an attempt should be made to retrospectively analyze the data to test the relationship between long-term noise exposure and cardiovascular health.

The recently funded NIH/NHLBI sponsored epidemiologic study (see Section 4.1.4) should provide a test and possible validation of some of the foreign studies which have reported positive associations between long-term noise exposure in the workplace and various cardiovascular health problems. Preliminary results should be available prior to the initiation of the planned small-scale prospective study.

Expected Results.--Work completed under this component should provide both a systematic replication of existing epidemiologic research and guidance and direction for future noise effects epidemiologic research.

Results to Date.--EPA has initiated an epidemiology feasibility study on the cardiovascular effects of noise. This study has three purposes: 1) to provide an objective and detailed evaluation of existing epidemiologic research on the nonauditory effects of noise; 2) to assess the applicability of non-noise related research on hypertension, cardiovascular disease and stress physiology to epidemiologic studies of noise effects; and 3) to discuss and make recommendations regarding a number of substantive and methodological issues that must be considered in designing a program of epidemiologic research on the nonauditory health effects of noise. The results of this study should be directly applicable to the design of future epidemiologic studies.

A second study initiated by EPA involves an analysis of data of the 1971 to 1975 National Health and Nutrition Examination Survey (HANES). This project takes advantage of a very large data base which contains extensive health examination and self-report data on a sample of the Nation's population. The nonauditory effects portion of the analysis will focus on modelling the associations between indirect indices of noise exposure, background characteristics and health status, and hypertension. Indices of noise exposure have been derived from occupational classifications and industrial codes. Preliminary analyses from the hearing loss segment of the study (see Section 7.2.1.I) have borne out the credibility of the noise exposure classification scheme. Self-report data on the history of a variety of medical conditions will be evaluated as well as the results of the general medical examination. Drug and medication usage data and suggested biochemical indicators will similarly be examined for their possible association with indices of noise exposure.

## Component II. Prospective analysis.

### Phase I - Small scale prospective study

A relatively small, well-controlled prospective study should be initiated subsequent to the completion of the EPA-sponsored epidemiologic feasibility study. Although the need for prospective data is obvious, the exact nature and precise timing of the study should, in part, be dependent upon the results of the feasibility study. It is anticipated that the study would be conducted in a work setting and involve some type of intervention scenario such as the institution of a hearing conservation program or other type of noise control measure. An attempt should be made to control for all the important variables affecting the outcome measures except noise.

Detailed noise measurements should be made of the current environment, and these should be repeated on a regular basis throughout the study. Dosimeters should be used to determine individual noise exposures, both inside and outside the work environment, over a 24-hour period. As a minimum, the project should include unbiased multiple measures of blood pressure, electrocardiograms (perhaps some type of continuous monitoring), assessment of hormonal responses to noise, standard blood chemistry, and hearing acuity. Emphasis may be placed on those individuals at high risk. Detailed medical histories and noise exposure histories should be obtained, as well as symptom checklists and demographic, socioeconomic, behavioral and physiologic indicators. Data should be collected for a period of at least 3 years.

Expected Results.--The prospective study should provide a test of the causal hypothesis linking noise exposure to cardiovascular health problems.

Phase II - Inclusion of noise as a factor in ongoing NIH cardiovascular research

The small-scale prospective study should be useful in determining the extent to which a causal relationship exists between noise and hypertension and other cardiovascular problems. If promising results are obtained, an attempt should be made to include actual noise exposure as a factor in ongoing and/or planned large-scale NIH longitudinal cardiovascular research. In association with these studies of cardiovascular disease, measurements of noise exposure should be made as well as measurements of risk factors such as improper diet, cigarette smoking, hypertension, high levels of serum cholesterol, sedentary life style, and diabetes mellitus. These studies should contribute greatly to knowledge concerning effects of noise in relation to other risk factors for cardiovascular disease. It is only through such research that the contribution of noise relative to other risk factors can be assessed in a sample large enough for generalization. Such an effort would contribute to the development of valid dose-response criteria.

Expected Results.--The addition of noise to large-scale NIH research should provide a sample large enough for generalization.

## Component III. Investigation of special sub-populations.

### Phase I - Blood pressure in children

Tentative data concerning elevations in blood pressure and a fairly extensive literature on cognitive development suggest that children may constitute a population susceptible to the nonauditory effects of noise. In the biomedical research community there is also concern about the prevalence of essential hypertension in children and the predictive value of childhood blood pressure labilities and elevations. A basic question concerns the relative contributions of genetic and environmental factors to the development of blood pressure elevations in children. An initial investigation should be undertaken to examine the role of noise in one of several ways: 1) through an expansion of the Fels Research Institute longitudinal hearing loss study, 2) by adding noise exposure measurements to one of the several ongoing childhood blood pressure studies sponsored by NIH, or 3) by including blood pressure as a component in planned research on the effects of noise on cognitive and language development and school performance.

The NSF/NIEHS-supported noise and children study and the NIH/NICHHD-funded study on noise and physical development (see Section 4.1.4) are both near conclusion and should provide information for use in the design of a blood pressure and children research effort.

Expected Results.--This research should begin to determine whether young children are particularly susceptible to the cardiovascular effects of noise.

## III. Human studies and clinical investigations of cardiovascular and neuroendocrine responses to noise

Description and Basic Considerations.--The purposes of this Initiative are to determine the effects of noise on blood pressure, cardiovascular function, metabolic activity, and endocrine response under controlled conditions. In particular, the characteristics of noise-causing cardiovascular and neuroendocrine responses should be determined as well as the characteristics of subjects most susceptible to physiological effects of noise. Eventually, it should be possible to identify sources of noise and conditions of exposure to noise most likely to cause cardiovascular disease and to identify people at greatest risk for developing cardiovascular disease when exposed repeatedly to noise over long periods of time.

This research should take advantage of advanced biochemical assay procedures and "state of the art" physiological recording instrumentation and techniques. Human experimental studies offer a much needed complement to the planned animal experimental and human epidemiologic studies. The human studies permit the exercise of control not available in epidemiologic research and acquisition of data on the organism of interest: humans.

### Component I. Investigations of acoustic and nonacoustic factors.

Systematic attention should be given to the role of acoustic factors such as level, frequency spectrum, and temporal pattern. The effects of acoustic factors should be assessed by elevations in blood pressure, blood lipid levels, and concentrations of hormones that are associated with altered cardiovascular and metabolic function in human subjects. These systematic studies of acoustic factors are essential to determine potential for interactions with nonacoustic factors.

The effects of nonacoustic factors also should be studied systematically. Physiological effects of noise appear to be aggravated by type of the noise, what the noise is associated with, where and when the noise occurs, and possibilities for controlling the noise. Investigations should be carried out to assess the role of contextual factors such as controllability, aversiveness, meaning, familiarity, contingencies, and task load.

The recently initiated U.S. Navy studies (see Section 4.1.4) should provide some data applicable to understanding the contribution of certain acoustic and nonacoustic factors.

### Component II. Investigations of differences in susceptibility.

Experiments should be conducted to determine which individuals are most susceptible to the effects of noise on cardiovascular and metabolic function. Not all individuals appear to be equally affected by noise and some may not be affected at all. However, individuals with high levels of blood pressure and individuals with labile blood pressure may be affected more than others. Individuals with neurogenic forms of hypertension may be affected most of all. Also, as some recent evidence suggests, individuals displaying certain behavioral patterns such as "type A" behavior may be particularly susceptible to the stress effects of noise. Those subjects most susceptible to adverse effects of noise should be identified in controlled laboratory experiments with measurements of physiological responses caused by noise. Those acoustic and nonacoustic factors most likely to aggravate the effects of noise should be introduced systematically to determine which individuals are most affected by noise under the most extreme conditions. Dose-response relations could then be determined with each type of individual in each experimental situation. Eventually, studies of susceptible individuals should be carried out in long-term prospective studies under exposure to different levels of noise under natural daily conditions.

The NIH/NHLBI and VA experimental studies mentioned in Section 4.1.4 are scheduled to end in the relatively near future. Thus their results could contribute to the design of the research suggested under this Initiative.

Expected Results for Components I and II.--

1. Provide data on the time course of response, rate of recovery, and adaptation of physiological responses to noise.
2. Assess individual differences in these responses.
3. Assess the role of various acoustic and nonacoustic factors in influencing these responses.
4. Provide human data to complement and verify the findings obtained in the primate research.

Results to Date for Components I and II.--Research has been initiated at the John Hopkins University Medical School directed at assessing the relationship between noise stress and aspects of human cardiovascular function. The schedule of proposed experiments is designed to study the effects of the basic properties of the noise stimulus, the pattern of physiological response, the pattern of change over time associated with repetitious stimulation by noise, and the interaction of noise with simulated work stress and resting baseline blood pressure. The first two experiments should involve relatively short exposure durations, while the third experiment should be conducted in a residential laboratory environment. The third experiment will begin to investigate differences in susceptibility in that participants will be selected on the basis of having high and labile levels of blood pressure and "Type A" behavioral patterns. The results of these experiments should provide initial information pertinent to the purposes of each of the human experimental components, and should provide considerable guidance for the design of future studies.

### 4.2.2 Secondary Research Initiatives

- Nonauditory physiologic effects other than cardiovascular effects

This Research Initiative is recommended to be undertaken by research organizations once the "priority" Initiatives have received adequate attention.

Description and Basic Considerations.--The purposes of this Initiative are: to evaluate the state of knowledge with respect to the nonauditory physiologic effects of noise other than cardiovascular effects; to establish research priorities among these effects areas on the basis of health impact and feasibility; and to outline research plans in each of these categories.

As discussed in Section 4.1.3, the initial focus of research on the nonauditory physiologic effects of noise should be on cardiovascular system effects. This, however, does not mean that there are not other important areas in which research is needed. The areas listed below represent important topics in terms of public health. Exploratory research has thus far yielded provocative and potentially important findings in these areas.

If funding constraints dictate that full-scale efforts in these areas cannot be initiated immediately, preliminary studies should be initiated in selected areas as soon as possible. The start-up of this work should not await the completion of all cardiovascular effects Initiatives.

The program as outlined should begin with a series of literature reviews and research planning activities. Although it is not possible to discuss specific research components in detail, the following are some of the priority areas:

- Laboratory and field studies of other medically significant responses to noise.--Noise, as a nonspecific physiologic stressor, is capable of producing a number of responses in the organism. Although the cardiovascular effects have been selected as the initial focus, other effects such as gastrointestinal effects have been reported and these need systematic study. Noise may operate by increasing susceptibility to a range of stress-related health conditions, and the same stressor (noise) may produce effects in different organ systems in different individuals.

- Descriptive and correlational field studies of the relationship of noise to health symptoms, complaints and behaviors.--There is a need for community-based studies to verify and extend previously reported findings of increased stress-related symptomatology, drug usage, physician visits, hospital admissions, etc.

- Determine whether living and/or working in high noise environments is associated with: (1) difficult pregnancies, (2) births with complications, (3) low birth weights, (4) and other reproductive/sexual dysfunctions.--Based on recent work, initial emphasis might best be placed on low birth weight and its neurological and behavioral implications.

- Investigations of the effects of noise on the physical growth, development and general health of children.--Evidence suggests that children may be a susceptible population with respect to noise effects.

- Interaction of noise with other stressors and environmental hazards.--Since noise seldom occurs by itself, laboratory and field studies are needed on the interaction of noise with other stressors and environmental hazards. Research should proceed with examination of noise occurring with other prevalent physical stressors such as heat, crowding, and toxic substances. The interaction of noise with various psychosocial stressors should also be considered. Primary candidates would include task load and other forms of occupational and interpersonal stressors. The greatest and most serious effects of noise may occur in these interactive situations.

## 4.3 Sequencing of Research Initiatives

The research Initiatives and their respective components should be executed in a logical and coordinated fashion. The research program as planned is designed to represent a graduated, time-phased effort. Efforts in each of the Initiatives should proceed concurrently,

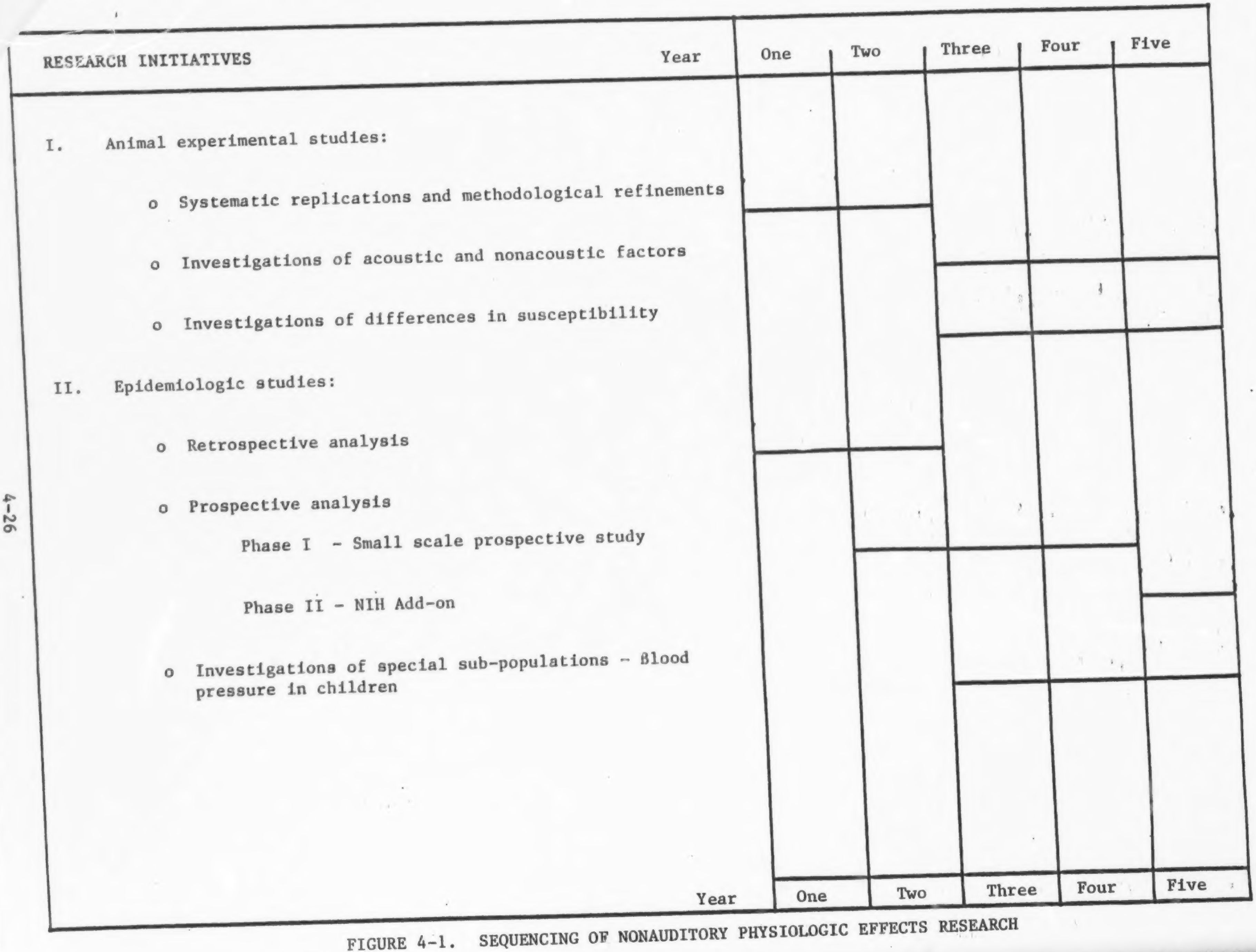


FIGURE 4-1. SEQUENCING OF NONAUDITORY PHYSIOLOGIC EFFECTS RESEARCH

| RESEARCH INITIATIVES<br>Year | One | Two | Three | Four | Five |
|---|---|---|---|---|---|
| III. Human studies and clinical investigations | | | | | |
| o Investigations of acoustic and nonacoustic factors | | | | | |
| o Investigations of differences in susceptibility | | | | | |
| IV. Other nonauditory physiologic effects: | | | | | |
| o Scientific appraisals | | | | | |
| o Selected studies | | | | | |
| | | | | | |
| Year | One | Two | Three | Four | Five |

FIGURE 4-1. SEQUENCING OF NONAUDITORY PHYSIOLOGIC EFFECTS RESEARCH (CONTINUED)

and the components within a given Initiative should be carried out in the sequence shown in Figure 4-1. Some overlap between components is unavoidable, but ideally the results of each study should feed into the approach and design of the next study. Figure 4-1 portrays the graduated timing and sequencing for the identified Research Initiatives on the Nonauditory Physiologic Effects of noise. Each Initiative may take more or less time than estimated on the Figure, depending upon the comprehensiveness of the research design, methodological problems that may arise, the number of studies under each Initiative, and, of course, the resultant findings. The results of early research should serve to estimate the relative contribution that a particular Initiative or approach will have on the success of the total program.

The reader should note that an in-depth Detailed Cardiovascular Research Plan has also been prepared by EPA. The Plan lays out a comprehensive program for the eventual development of dose-response criteria. Complete funding and timing figures are included in that Plan. Thus, the reader desiring a more detailed description of recommended research in this category in pursuit of dose-response criteria should obtain a copy of the Detailed Plan from EPA.

# 5. RESEARCH PLAN FOR SLEEP DISTURBANCE

# TABLE OF CONTENTS

Contents — Page

5.1 Rationale for Selecting Specific Research Initiatives 5-1
  5.1.1 What is Known 5-1
  5.1.2 What is Not Known 5-4
  5.1.3 Priorities 5-5
  5.1.4 Current Research Activities 5-6
  5.1.5 Position on the Research Continuum 5-7
  5.1.6 List of Priority Research Initiatives Necessary Better Support Public Health and Welfare Needs 5-7
5.2 Detailed Description of the Research Initiatives 5-9
  5.2.1 Priority Research Initiatives 5-9
    I. Relationship between field and laboratory data on sleep disturbance by noise. 5-9
    II. Health consequences of noise-disturbed sleep. 5-10
    III. Acoustic parameters related to sleep disturbance. 5-12
    IV. Susceptibility of sensitive populations to sleep disturbance by noise. 5-13
    V. Adaptation to sleep disturbance by noise. 5-14

# 5. RESEARCH PLAN FOR SLEEP DISTURBANCE

## 5.1 Rationale for Selecting Specific Research Initiatives

The long-term objective for research on sleep disturbance is to determine and quantify effects of noise on sleep, and its implications for general health and performance.

### 5.1.1 What is Known

About the Effects of Noise on Sleep Itself.--Everyone has experienced disturbances of sleep attributable to noise. The most obvious forms of disturbance are prolonging of the time initially needed to fall asleep, awakening once asleep, and interference with returning to sleep once awakened. Noise may also affect sleep in less apparent ways. One is by inducing shifts from deeper to shallower sleep stages, as measured electrophysiologically.* Another is by increasing bodily activity while asleep. Over a series of nights, given the same noise exposure characteristics, awakenings due to noise often become less frequent. On the other hand, noise-induced shifts from deeper to shallower sleep seem to persist over time. The net effect of chronic nightly noise exposure may be to reduce the amount of time spent in deep sleep relative to shallow sleep.

---

* The stages of sleep are measured by electroencephalograms (EEG). The EEG is a visual display of brain wave patterns that have meaning and organization.

People vary greatly from each other in their susceptibility to sleep disturbance by noise exposure. Individual susceptibility also varies from time to time and from situation to situation. The degree of familiarity with a noise is clearly a major determinant of sleep disturbance, especially awakening. Other factors, such as the meaningfulness of noise intrusions, their abruptness of onset, and their expectedness, duration, and intrusiveness seem to influence the likelihood of sleep disturbance. Also, the subject's age, sex, and state of health are known to play a role. For example, susceptibility to sleep disturbance increases with age from childhood through old age.

A general relationship between increasing noise exposure levels and increasing likelihood of sleep disturbance has been established. Based on empirical evidence, preliminary criteria have been derived for the probability that someone's sleep will be interrupted or changed from a deeper to a shallower stage.

About the Effects of Sleep Disturbance on Health and Performance.--The overall challenge to sleep researchers is to characterize the importance and functions of sleep physiologically and psychologically. Presently, the best indicators of the value of a night's sleep seem to be subsequent daytime task performance, and degree of sleepiness, as measured by objective and subjective tests.

These statements seem to be true for disturbance by noise as well as for other disturbances such as shiftwork. While effects on performance and sleepiness are often reported, more sensitive and reliable measures are being sought.

There is evidence in the research literature that the quantity of sleep is less important than its quality as measured by the regularity and organization of sleep depth (EEG) stages. Sleep quality has been found in some of the research to affect certain subjective, physiological and performance measures. Sleep quality is important in studying noise effects because a repeated noise may continue to disrupt the depth of sleep, even though it ceases to elicit awakening. Progress has recently been made in studying the correlates of sleep quality. Research in a number of different contexts is improving methodologies and instrumentation for studying patterns of sleep, biochemical changes and performance capabilities.

While the results of health studies are still inconclusive, in clinical practice the medical professions have long recognized the requirement for sleep, peaceful rest, and quiet in recuperation from illness. This implicit understanding of the importance of restful sleep seems to be shared by the public at large. People clearly feel a loss of competence and well-being from sleep disruption. The major subjective consequences of noise-induced sleep disturbance are fatigue, irritability, drowsiness, difficulty in work performance, and a diminishing in overall feeling of well-being. According to EPA's Urban Noise Survey,* of those persons who said they had been bothered by noise in their neighborhoods, 60 percent cited sleep disturbance as one of the most common and annoying aspects of the problem.

---

* The Urban Noise Survey, EPA Report 550/9-77-100, August 1977.

### 5.1.2 What is Not Known

About the Effects of Noise on Sleep Itself.--While forming an adequate basis for Federal regulatory purposes, present criteria are in need of refinement. A difficulty with available information about noise-induced sleep interference is that much of it is derived from laboratory rather than field study. It is possible that some of the effects of noise on sleep demonstrated under laboratory conditions may be different in familiar residential settings. Further, it is important to learn the degree to which habituation and/or sensitization to nightly noise are expressed in sleep patterns of people in their homes.

Refinement is also necessary to relate noise exposures to sleep disturbance among different segments of the population. Special groups that may be more adversely affected include the elderly, shiftworkers, and the ill. Further, across all population categories it is important to understand the influence of such factors as drug consumption, attitudes, and expectations related to "good" and "bad" sleep.

Another need is to know how noises of different acoustic characteristics affect sleep. Criteria developed on the basis of some major noise sources may have limited applicability to others. It has been suggested that response patterns of people exposed to traffic noise are different from responses to noise from other sources such as aircraft.

About the Effects of Sleep Disturbance on Health and Performance.--Research on the health and performance consequences of sleep disturbance has only recently gained ground. Many potential measures of health and performance have not yet been systematically explored or applied to sleep questions. Consequently, the ultimate seriousness of chronic sleep disturbance due to noise has yet to be determined.

### 5.1.3 Priorities

The major research need is the determination of the effects of acoustic and nonacoustic variables on sleep quality. To support this goal, meaningful response measures of sleep disturbance that would aid in conducting research should be developed. More information is needed about sleep patterns in residential rather than laboratory settings, and about the incidence of chronic sleep disturbance in the United States, especially as it is attributable to different noise sources. In this regard, it is important to characterize noise exposures not only during the sleeping hours, but throughout the day as well. It is also necessary to determine the degree to which habituation and/or sensitization to noise exposure occurs. If people adapt to noise disturbance of sleep, the biological costs of the adaptation need to be defined and quantified, both in short and long term.

It is necessary to define sleep quality both physiologically and behaviorally. Further, it is important to study physiological and psychological correlates of sleep disturbance, and to examine any implications of chronic noise-induced sleep disturbance on general health and performance. Also, it is necessary to identify any population subgroups that may be especially susceptible to noise-induced sleep disturbance and to determine the consequences of this disturbance.

### 5.1.4 Current Research Activities

There is only limited Federal research to date on these particular topics. Over the last five years expenditures by other Federal agencies for sleep-related noise studies have totaled only a little over $350,000, and have covered only some of the subtopics of sleep research relevant to noise effects research. Currently, EPA is undertaking a study of health consequences of chronic sleep disturbance by noise. This study will assess physiologic activities in both field and laboratory environments. Persons who are chronically exposed to nighttime noise at home will be compared to a control group on a wide range of health-related measures.

Some of the related Federal and International research projects ongoing in Fiscal Years 1980-81 include:

o The National Institute for Child Health and Human Development is studying parameters of infants' sleep in the context of the Sudden Infant Death Syndrome. This work is developing respiratory, cardiovascular, and other correlates of infant sleep patterns.

o The Walter Reed Army Medical Center has a continuing program of research on disrupted sleep and its health and performance implications. One current focus is performance measures as related to sleep quality.

o The National Institute for Mental Health is conducting a study of levels of arousal in insomniac patients following auditory stimulation.

- A set of joint research projcts sponsored by the Commission of European Communities (EEC) is yielding valuable information on heart rate, performance, and subjective response to sleep disturbance by noise. These in-the-home studies from the United Kingdom, the Netherlands, France, and West Germany, are investigating the sleep disrupting effects of traffic noise levels. The results may be published in late 1981 or early 1982.

### 5.1.5 Position on the Research Continuum

As can be seen in Table 5-1, preliminary criteria have been established based on how noise disturbs sleep. These criteria form an adequate basis for comparing noise control options by quantifying the short-term effects of noise on sleep. However, the subsequent health and performance effects of noise-disturbed sleep are among the least understood effects of noise, owing to the present inability to fully define the functional value of sleep, among other factors. Currently there is a great deal of sleep research focusing on respiratory activity, temperature, and other circadian rhythms, and sleep as a function of age. Results of this research are anticipated to be available to input to the Research Initiatives listed below.

### 5.1.6 List of Priority Research Initiatives Necessary to Better Support Public Health and Welfare Needs

After reviewing the status of noise-induced sleep disturbance research, environmental noise program needs and priorities, and the planned research activities of other Federal agencies, the following

## TABLE 5-1

## POSITION ON THE RESEARCH CONTINUUM - SLEEP DISTURBANCE

| Research Continuum | Current State of Knowledge | | |
|---|---|---|---|
| | Adequate | Marginal | Inadequate |
| 1. Demonstrate existence of an association | y[1] | x[2] | |
| 2. Demonstrate basic cause-effect relationship | | | |
| A. Animals | y | | x |
| B. Humans | y | | x |
| 3. Investigate physiologic mechanisms | | y | x |
| 4. Investigate intervening factors Improve cause-effect relationship | | | |
| A. Acoustic | | y | x |
| B. Nonacoustic | | | y,x |
| 5. Quantify dose-response relationship | | y | x |
| 6. Refinement and special populations | | y | x |

---

[1] The rating "y" refers to the status of research on the short-term effects of noise on sleep itself.

[2] The rating "x" refers to the status of research on the health and performance consequence of sleep disturbance.

priority Research Initiatives are recommended. They are listed roughly in chronological order because each contributes information to others in a logical sequence. Note that each Initiative may contain a number of different studies, but details of each study are not given at this time.

I. Relationship between field and laboratory data on sleep disturbance by noise

II. Health consequences of noise-disturbed sleep

III. Acoustic parameters related to sleep disturbance

IV. Susceptibility of sensitive populations to sleep disturbance by noise

V. Adaptation to sleep disturbance by noise

## 5.2 Detailed Descriptions of the Research Initiatives

### I. Relationship between field and laboratory data on sleep disturbance by noise

Description and Basic Considerations.--Present criteria used to quantify sleep disturbance (the probability of shifts in sleep depth, and awakening) are based largely on the sleep of subjects measured under laboratory study conditions. There is a need to relate sleep as measured in the laboratory to sleep at home. Further, subjective sleep quality as reported by people sleeping at home has never been fully validated or related to objective sleep measures. This Initiative, therefore, is designed to improve existing criteria by determining the relationship of sleep in the laboratory to sleep at home. The sleep of persons living in areas of high nighttime noise should be studied both in their homes and in the laboratory. Noise in the home should be recorded and played back in the laboratory "bedroom." Subjective assessments of sleep quality should be compared to objective measures, with the aim of establishing a valid and reliable subjective measure applicable to noise research.

This information can be used in subsequent Research Initiatives dealing with the longer term health and performance impact of noise-disturbed sleep.

Expected Results.--Correction factors, transfer functions or new criteria are expected which, when applied to laboratory data, may be used to predict the magnitude of noise-related sleep disturbance in the home environment. Such correction factors should permit refinement of present criteria. Depending on the results, these studies may also reduce the need for extensive in-the-home research. A valid and reliable subjective sleep quality measure would aid in this endeavor. Results from research under the Health Consequences Research Initiative (see discussion below) should assist in validating the laboratory-home correction factor to be derived under the present Initiative.

## II. Health consequences of noise disturbed sleep

Description and Basic Considerations.--This Initiative is designed to objectively define and quantify the impact of noise-disturbed sleep on general health and performance. Although complete information cannot be gained within a short time, it is anticipated that significant accomplishments could be made within a five-year period. This Initiative consists of two components, animal and human studies.

Component I--Human studies:

These studies should investigate parameters such as medical records, absenteeism, and biochemical, physiologic and performance measures. In regard to physiologic measures, EPA began in 1981 an initial study with the Stanford University School of Medicine. The objectives of the study are: (1) to determine by a number of simultaneous physiological and other measures in the field, the effects of noise on sleep and subsequent daytime functioning, and (2) to test for recuperation or improvement in these parameters as a result of quiet, undisturbed sleep in the laboratory. Cardiovascular, respiratory, electrophysiological, and other functions will be monitored in the field, as subjects conduct their everyday activities (including going to work and running errands as usual, and sleeping in their own beds with usual bed partners). Data will be collected by means of an 8-channel microprocessor small enough to be conveniently worn 24-hours-a-day, for a week or more at a time. Data on sleep physiology and acoustics will be transmitted by existing telephone lines in the subjects' homes. Laboratory portions of the study will test daytime performance, objective sleepiness, periods of microsleep, and nighttime sleep physiology in a quiet residential environment. Because this research involves cardiovascular, respiratory and other physiologic measures monitored in the field and laboratory, the results of the study will also contribute to Nonauditory Physiologic Effects Research Initiatives.

### Component II--Animal studies:

Animal studies under well-controlled conditions should be conducted for the most part, in parallel with the human studies component. Under controlled conditions, animals (primates) should be used to study the biochemical and electrophysiological parameters related to sleep disturbance, health, and performance. Animal research can answer many questions which cannot be explored directly in humans. Animal noise exposures and other factors can be precisely controlled, and a broad range of biochemical and physiological measures can be studied, using invasive techniques if necessary.

Initial research should consist of primate studies exploring physiological parameters and protocols best suited to related human research.

### Expected Results of Components I and II--

1. A preliminary objective definition and measurement of the value of sleep for health and performance, and progress in the ability to measure the deficits due to sleep disturbance by noise.

2. Validation of the laboratory-home correction factor to be derived from Initiative I.

3. Significant progress toward quantified relationships between noise-disturbed sleep and other health and performance measures to be specified in the course of the research.

## III. Acoustic parameters related to sleep disturbance

Description and Basic Considerations.--The basic thrust of this Initiative will be to assess how different types of noise (as from different noise sources) differentially affect sleep. Existing criteria are based mainly on responses to aircraft overflights. Their specific application to sources such as trucks, buses, automobiles, rapid transit vehicles, railyards, construction equipment, household appliances, and garden and shop tools should be studied. Studies should specifically investigate the effects of rise time, frequency spectra, duration, vibration concomitant with noise, impulsiveness, intermittency, and intrusiveness over background levels.

Expected Results.--A family of sleep disturbance criteria for different noise characteristics and sources should be derived. This information will assist in the quantification of the benefits of specific noise control actions, and also contribute to the Health Consequences Initiative (II). Correction factors developed from Initiative I, assessing differences between home and laboratory studies, may be applied.

## IV. Susceptibility of sensitive populations to sleep disturbance by noise

Description and Basic Considerations.--Existing studies and criteria are based mainly on the sleep of young, healthy male students. Susceptibility to sleep disturbance is known to vary with age and other factors (e.g., the elderly are highly susceptible to sleep disturbance). No special criteria exist for these groups at this time. Under this Initiative, sleep disturbance for special populations such as the elderly, middle-aged people, children, the ill, and the growing number of nightshift workers would be quantified.

_Expected Results_.--The long-term objective of this Initiative is to derive a family of sleep disturbance criteria (by noise) for people of different ages, states of health, occupations, and lifestyles.

## V. _Adaptation to sleep disturbance by noise_

_Description and Basic Considerations_.--Using both short-term (behavioral and electroencephalographic) as well as other measures (biochemical, health and performance) derived from previous Initiatives, these studies should determine degrees of adaptation, habituation and/or sensitization to noise disturbance over time (in terms of years of chronic exposure).

_Expected Results_.--Long-term objectives of this Initiative are to derive revised criteria for sleep disturbance and awakening, and preliminary criteria for the long-term effects of noise-disturbed sleep on general health and performance.

# 6. RESEARCH PLAN FOR INDIVIDUAL AND COMMUNITY RESPONSE

# TABLE OF CONTENTS

Contents Page

6.1 Rationale for Selecting Specific Research Initiatives 6-1

- 6.1.1 What is Known 6-1
- 6.1.2 What is Not Known 6-3
- 6.1.3 Priorities 6-4
- 6.1.4 Current Research Activities 6-5
- 6.1.5 Position on the Research Continuum 6-7
- 6.1.6 List of Priority Research Initiatives Necessary to Better Support Public Health and Welfare Needs 6-7

6.2 Detailed Descriptions of the Research Initiatives 6-10

- 6.2.1 Priority Research Initiatives 6-10
  - I. Determination of the magnitude of community and individual response attributable to specific sources of noise. 6-10
  - II. Determination of the relationship between specific acoustic attributes and the magnitude of individual/group response to noise. 6-12
- 6.2.2 Secondary Research Initiatives 6-15

## 6. RESEARCH PLAN FOR INDIVIDUAL AND COMMUNITY RESPONSE

For purposes of brevity, this category will be referred to as "community response" in this chapter.

### 6.1 Rationale for Selecting Specific Research Initiatives

The long-term objective for research in this category is to determine and quantify subjective reactions of individuals and communities to different noise environments and sources, and to investigate mediating factors.

### 6.1.1 What is Known

Information is available about individual and community response to commonly occurring forms of noise exposure. The major physical determinants of both individual and community annoyance due to noise are understood in fair depth. For example, most of the variability in individual judgments of annoyance associated with noise can be accounted for under laboratory conditions by a number of objective physical measurement procedures.

Psychoacoustic research in the last two decades has refined the long-known relationship between the frequency sensitivity of human hearing and annoyance judgments. Scales of varying complexity, some directly readable from simple instrumentation, others requiring complex computations, are commonly used to predict the annoyance of a great many noise sources. The combined effects of pure tones and duration of sounds, among other factors, are known to influence annoyance reactions to noise, but research has not yielded the anticipated applications to the community environment.

General relationships of overall community response to noise (the central tendency of large numbers or groups of individuals) have been derived and are commonly used for noise assessment purposes. Virtually no information is available regarding the objective responses of different individuals (that is, individual variations are generally "averaged out" in commonly used community response measures).

It is also known, however, that nonacoustic factors, such as attitudes toward noise sources, or the particular activities disturbed (such as interference with speech communications and disturbance of sleep) can affect both individual and community reactions to sound. Thus, although many determinants of individual and community annoyance are well understood on a global level, this general knowledge will not yet support precise situation-specific predictions of individual or community response to noise exposure.

The prevalence of annoyance due to noise exposure throughout American society is known in considerable detail. It is known, for example, that annoyance due to noise exposure is not restricted only to neighborhoods near airports, highways, and other major noise sources, but that exposure to levels typical of many urban environments also produces widespread annoyance. Noises associated with automotive sources (e.g., street traffic noise) are the most universal sources of annoying noise exposure in urban America.

Cumulative measures of total outdoor noise levels (for example, $L_{dn}$, the Day-Night Sound Level) have been shown to provide a useful reflection of community reaction, at least at higher exposure levels. Thus, the proportion of a community highly annoyed by noise exposure can be reliably predicted from objective measures of noise levels. Demographic factors such as age, sex, and socioeconomic status do not appreciably affect the accuracy of such calculations.

### 6.1.2 What is Not Known

Quantitative information is still lacking on the influences of a number of factors that may affect individual and community response to noise exposure. On an individual basis, considerable uncertainty remains about the annoyance of specific noise intrusions superimposed on the ambient noise environment. Other unsettled issues concern the annoyance associated with exposure to unusual and unsteady sounds. These include sounds that may vary in level over time, sounds of very short duration, and sounds that occur infrequently, intermittently, or unpredictably. The precise influence of audible pure tones in the noise, unusual spectral composition, and the presence of impulsiveness is open to question. It is also not clear how the immediate annoyance of noise intrusions is affected by the nature of an individual's ongoing activities at the time of the noise intrusion. The manner in which people integrate or cumulate annoyance or other adverse reactions over time, especially considering differing individual lifestyles and associated exposures, is not at all understood.

On the community level, the effects of noise exposures at different times of the day and seasons of the year are not fully resolved, nor are the effects of temporary (as opposed to long term) exposure, or numbers of discrete noise events. Although existing criteria are judged adequate for Federal regulatory purposes, a controversy exists as to differences in annoyance response that may be attributable to specific yet different sources of noise such as construction noise, recreational noise, household noise, and so forth, as well as reactions that occur in special noise environments such as in transit, in commercial areas, vehicles or work places.

The influence of accompanying nonacoustic variables such as people's preconceived attitudes toward or associations with particular sources of noise are not understood. Questions of annoyance and stress upon special population groups such as children, the elderly, and the ill, as well as the variability in annoyance response between individuals, have not been addressed.

In addition, little is known about annoyance response to low levels of noise. The variability of individual annoyance judgments on low level noise cannot yet be accounted for on the basis of physical (acoustical) parameters of the noise. Yet there are environmental settings such as parks, and residential, recreational and wilderness areas, where such annoyance certainly exists.

### 6.1.3 Priorities

Priorities for national, State and local noise programs require that research attention be focused on individual and community response to a variety of special sources of noise exposure, including construction activity, railroads, household and consumer products, mass transit, noise sources in outdoor recreational areas, blast noise, and certain forms of air and ground transportation. For example, more specific criteria for construction sites may be needed to support State and local construction site noise abatement programs.

Determining the relationship between specific attributes of noise and the magnitude of individual or community response will require further research attention for the same programmatic reasons. The specific noise attributes that should be addressed are noise with pronounced tonality or unusual spectral composition, fluctuating levels, and impulsive components; vibration concomitant with noise; noise of varying duration, time of occurrence, and number of discrete occurrences; and noise of varying intrusiveness.

The influence of a number of nonacoustic factors on individual and community response also requires more careful study. These include contextual factors such as the purpose of noise emissions (e.g., warning signals), the perceived ability to control the noise emission exposure, and certain attitudes toward the sources of noise exposure. The response of certain, identifiable special population groups who may be especially susceptible to the noise also deserves study.

### 6.1.4 Current Research Activities

EPA has undertaken a project to design a study protocol for investigations of community reactions and attitudes toward construction noise. This project, "The Construction Site Noise Attitudinal Survey," is being undertaken in cooperation with the U.S. Army Construction Engineering Research Laboratory. The protocol being developed for the administration of construction site attitudinal surveys will detail the physical noise measurement protocol, site selection plans, attitudinal questionnaires for both residential and non-residential areas, respondent sampling plans, and equipment and personnel needs.

An additional EPA study has been undertaken to assess human response to the repetitive-type impulse noise associated with engine brakes used on many trucks and buses. The primary aim of this study is to examine the ability of existing analysis methods and sound descriptors to acceptably account for anticipated human response to the peculiar characteristics of engine brake noise. Comparison with existing correction procedures will be made, and new predictive techniques or adjustments will be offered where appropriate. A secondary aim is to gain a more in-depth understanding of human response to repetitive impulsive noise in general, and to better relate human response to relevant acoustic and psychological factors.

Over $800K per year has been spent by other Federal agencies in the area of individual and community response to noise over the last several years. Of the three agencies primarily active in this category, NASA leads the way, with over eight projects and more than $400K devoted to such studies. However, these activities concern mainly aircraft noise. Some of the specific Federal research activities in Fiscal Years 1980-1981 include the following:

- NASA study of the validity of the 10 dB nighttime weighting penalty applied to aircraft noise;
- NBS (National Bureau of Standards) investigation of the human response to time-varying traffic noise;
- A U.S. Air Force study assessing the impact of Air Force aircraft noise activities;
- A U.S. Army laboratory study on human response to high energy impulse noise;
- A NASA project to determine the most effective descriptors for multi-event aircraft noise exposure;
- A NASA study to ascertain the annoyance characteristics of helicopter noise.

### 6.1.5 Position on the Research Continuum

As indicated in Table 6-1, preliminary criteria exist for quantifying the relationship between general community annoyance response and higher level noise exposures. However, little is known about the effect of lower level exposures, intervening factors, and effects on special populations.

### 6.1.6 List of Priority Research Initiatives Necessary to Better Support Public Health and Welfare Needs.

After reviewing the status of community and individual response research, environmental noise program needs and priorities,

## TABLE 6-1

## POSITION ON THE RESEARCH CONTINUUM - INDIVIDUAL AND COMMUNITY RESPONSE

| Research Continuum | Current State of Knowledge | | |
|---|---|---|---|
| | Adequate | Marginal | Inadequate |
| 1. Demonstrate existence of an association | x | | |
| 2. Demonstrate basic cause-effect relationship | | x | |
| 3. Investigate response mechanisms | | | x |
| 4. Investigate intervening factors. Improve cause-effect relationship | | | |
| A. Acoustic | | x* | |
| B. Nonacoustic | | | x |
| 5. Quantify dose-response relationship | | x* | |
| 6. Refinement and special populations | | | x |

*Although rated as marginal, the only parameter that has been substantially quantified and is fully usable for noise assessment purposes is that of perceived amplitude or intensity (level).

and the planned activities of other Federal agencies, the following major Research Initiatives are recommended as priority research needs.

I. Determination of the magnitude of community and individual response attributable to specific sources of noise

II. Determination of the relationship between specific acoustic attributes and the magnitude of individual/group response to noise

In order to better understand the ensuing discussions under each Initiative and related components, the reader should note the following factors and assumptions:

1. Each Initiative, and each component thereof, may contain a number of different studies, but the details of each study are not provided at this time.

2. Sequencing of studies according to priorities may be necessary because of typical resource constraints heretofore experienced in this category. However, an assumption of resource constraints has not influenced the selection of topics which have been identified, based upon the consideration of urgency of need for the reseach.

3. Regarding the optimum size and balance of research in this category given assumed funding constraints, it is anticipated that emphases would have to be placed in a few select studies or research areas. Therefore, the Components within each Research Initiative are grouped in descending order of priority based upon national urgency of need.

4. No component within any Initiative should be completed within the next few years due to assumed resource constraints. Thus, results may not yield quantitative relationships suitable for all conceivable applications.

## 6.2 Detailed Description of the Research Initiatives

### 6.2.1 Priority Research Initiatives

I. Determination of the magnitude of community and individual response attributable to specific sources of noise.

Description and Basic Considerations.--This Initiative consists of a number of components or topics important to environmental noise program needs.

The following topics are deemed to be of highest priority because of demonstrated, continuing legislative interest in the specific noise problems:

a. Ground transportation noise: The research objective is to refine currently available criteria for application to specific vehicular sources and special situations.

b. Railroad and rail facility noise: The research objective is to formulate criteria directly pertaining to this type of noise, including yard as well as main line activities.

The following topics are ranked at the next highest priority level because of widespread community concern:

a. Construction site noise: The research objective is to acquire community response data which will establish a relationship between noise exposure and the impact on people exposed, taking into account the varying longitudinal aspects of the noise exposure and the impact on two particular populations: residential and workday.

b. High energy impulsive noise: The research objective is to formulate quantitative criteria pertaining to human subjective response to this special type of noise, particularly in regard to sonic booms, artillery fire, and mining blasting.

The remaining priority topics are:

a. Household and consumer products/interior noise: The research objective is to formulate quantitative criteria pertaining to these special types of noises and/or situations of exposure.

b. Mass transit noise: The research objective is to formulate criteria directly pertaining to this type of noise, including community as well as passenger subjective response.

c. Recreational areas/offroad vehicles: The research objective is to formulate criteria pertaining to this special type of noise exposure.

d. Aviation noise: The research objective is to refine currently available criteria for application to special situations.

The above research areas should consider the impact of noise from the specific source, both alone and in combination with exposure from other sources of noise. Research should be conducted in each of these areas before determinations can be made on the relative differences in community response, if any, between different sources of noise. Such determinations are of high programmatic relevance on national, State and local governmental levels. Moreover, consideration should be given to the influence of noise as experienced by respondents in other situational contexts and locations upon their annoyance as well as other evaluative responses.

Expected Results.--

1. The program will ultimately yield dose-response type criteria (annoyance and/or other subjective evaluative attributes), although these criteria may be somewhat limited for many applications. In the case of construction noise, the study protocol that is to be developed will not, when implemented, have general application to all aspects of the construction noise problem. Further study should yield criteria directly applicable to construction noise for which no criteria already exist. The information derived from this research could be used to support either national, State or local noise control programs where interest in controlling various sources of noise has been expressed.

II. Determination of the relationship between specific acoustic attributes and the magnitude of individual/group response to noise.

Description and Basic Considerations.--This Initiative would encompass the development of modifications or adjustments to existing descriptors or metrics for rating human response, or the development of new formulations as necessary. This Initiative consists of three components.

A. In the first component human subjective response to intrusive noise should be studied. Formulation of a descriptor or metric that pertains to noise that intrudes into the environment for discrete periods of time (whether minutes, hours, days, or seasons) has been identified as a high programmatic need for noise programs. Cumulative predictive methods are not entirely adequate in a descriptive sense to account for this type of noise. This program would, in the initial years, consist of a series of laboratory psychoacoustic studies aimed at scaling the magnitude of subjective response to various degrees of "intrusiveness" or detectability of noise over a background. It would consist of a psychoacoustic laboratory investigation to determine the influence of the subjects' degree of involvement in various foreground tasks on their indicated annoyance by intrusive-type sounds; that is, subjective response to either single-event, short duration, or low-level noise, where currently employed cumulative noise descriptors may not fully reflect the effect of the noise. This is a necessary step before the development of a quantitative intrusiveness type annoyance scale.

B. Other components should be selected later on the basis of the latest assessment or program requirements. The most important topics are:

a. Impulsiveness: The research objective is to derive a descriptor or adjustment method to better ascertain the adverse subjective response of people to noise which is characterized by impulsiveness.

b. Fluctuating noise: The research objective is to develop a descriptor or adjustment method to ascertain adverse subjective response of people to noise that fluctuates in character over time.

c. Diurnal penalties: The research objective is to verify currently used adjustment methods with regard to the magnitude of human response as a function of time of day. This research has a direct bearing on the proposed research identified under Component I.

C. Other potential topics are:

a. Intrusiveness of low-level noise: The research objective is to conduct further work to develop criteria pertaining to low level noise (a problem noted in many areas where background noise is already low).

b. Tonality: The research objective is to develop a description or adjustment method to ascertain adverse subjective response of people to noise which contains perceptible tones.

c. Duration: The research objective is to develop a descriptor or adjustment method to assess the influence of duration on human subjective response.

d. Interaction of vibration and noise: The research objective is to determine the contribution to subjective human response caused by vibration concomitant with noise.

h. Multiple events: The research objective is to ascertain the manner in which people perceive and integrate multiple events over time as reflected in their subjective response.

Expected Results.—

1. The program on intrusive noise should yield criteria based on laboratory psychoacoustic studies that will be usable for limited application. Criteria will relate objectively measured

intrusiveness of noise to anticipated annoyance reactions. The need to proceed with additional work in this area depends upon adequacy of the research findings during the progress of the studies, and should be reevaluated periodically.

2. Depending upon the selection of one or more additional research components under this Initiative, research would yield additional, but preliminary, adjustment methods or descriptors with respect to the specific acoustic attributes, discussed above, that may influence the exact individual and community response to noise. As each topic is evaluated, it will be decided whether the related acoustic parameters are psychoacoustically important and require specification of a quantitative adjustment to the measured noise level in order to properly account for their influence on human response. The information derived from this research would be useful as a basis for regulatory and certification measurement procedures, as well as a focus for the development of noise control techniques.

### 6.2.[illegible] Secondary Research Initiatives

These are topics not discussed in detail in this Plan, but are recommended to be undertaken by research organizations once the more "priority" Initiatives receive adequate attention.

- Identification and quantification of nonacoustic determinants of community and individual response to noise.

This Initiative should not be directly undertaken now except as a complimentary component to Initiative I because (a) it is more important to acquire information on the acoustic determinants initially since they will have the most direct programmatic applications, and (b) it is not experimentally desirable to proceed to examine the nonacoustic parameters, unless the variation typically encountered in measuring human response to noise is minimized, to the greatest extent possible, by proper quantification of the acoustic factors.

Components within this Initiative include:

a. Influence of contextual factors and attitudes on response to noise.

b. Identification of nonverbal reactions to noise.

c. Determination of reactions to warning signals or other noises with a high degree of meaningfulness.

- Determination of susceptible population subgroups.

Criteria for source specific environments and acoustic/nonacoustic attributes are needed prior to the refinement of these criteria to account for especially sensitive or susceptible populations. The research under this Initiative should closely follow the lines of inquiry established in the Nonauditory Physiologic Effects category under Initiative III, Component II.

# 7. RESEARCH PLAN FOR NOISE-INDUCED HEARING LOSS

## TABLE OF CONTENTS

Contents — Page

7.1 Rationale for Selecting Specific Research Initiatives 7-1

- 7.1.1 What is Known 7-1
- 7.1.2 What is Not Known 7-3
- 7.1.3 Priorities 7-5
- 7.1.4 Current Research Activities 7-6
- 7.1.5 Position on the Research Continuum 7-9
- 7.1.6 List of Research Initiatives Necessary to Better Support Public Health and Welfare Needs 7-10

7.2 Detailed Descriptions of the Research Initiatives 7-10

- 7.2.1 Priority Research Initiatives 7-10
  - I. Determination of the prevalence of NIHL in the United States and the contribution of sociocusis (nonoccupational exposure), presbycusis (aging), and occupational exposures. 7-11
  - II. Establishment of parameters of individual sensitivity to NIHL. 7-13
  - III. Refinement of criteria for low-level noise exposure. 7-17
  - IV. Determination of social and economic impacts and other consequences of NIHL. 7-18
- 7.2.2 Secondary Research Initiatives 7-19

# 7. RESEARCH PLAN FOR NOISE-INDUCED HEARING LOSS

## 7.1 Rationale for Selecting Specific Research Initiatives

The long-term objective for research in this category is to determine the extent of the problem, causative factors, and associated effects.

### 7.1.1 What is Known

The prevalence of hearing loss among workers in industry has been recognized since the start of the industrial revolution. Within the last three decades a number of hearing loss studies in industry and in the laboratory have shown a direct relationship between hearing loss and the intensity and duration of noise exposure. Animal studies have shown that as the intensity and duration of noise exposure increases, a greater proportion of the sensory cells within the inner ear will be damaged and eventually destroyed. This will result in a permanent, irreversible loss in hearing sensitivity.

Noise-induced hearing loss (NIHL) increases most rapidly over the first 10-15 years of noise exposure in the higher frequencies of hearing sensitivity. Noise-induced hearing loss can result from daily noise levels as low as 75 dB after 10 years of exposure. Because the loss in hearing is so gradual, most people do not recognize the reduction in their hearing sensitivity until it is too late.

Hearing loss often causes a complete change in a person's social and work life. The hearing process is fundamental to the perception and understanding of speech, and persons with noise-induced hearing loss have great difficulty understanding speech when there is some noise in the background.

Industrial hearing loss studies have provided a set of quantitative damage risk criteria. Risk refers to the probability that a certain percentage of a noise exposed population will suffer NIHL in excess of a specified value. Specific noise limits have been proposed for the purpose of protecting workers' hearing based on these criteria. However, there is a great deal of individual variation in susceptibility to hearing loss. Industrial studies have shown a wide variation in hearing levels for worker populations of the same age and with the same occupational noise exposure. Animal experiments as well have shown substantial variations in the hearing damage of animals of the same species after comparable exposures. There is also some evidence that young animals incur more auditory damage than predicted for older animals. This finding has relevance to the issue of children and NIHL.

Some hearing surveys in the population have shown demographic differences in the hearing levels of different races, sexes, cultures and social groups. Certain people in remote areas of the world, who have not been exposed to the din of noise in our mechanized society, have much better hearing in comparison to urban populations of corresponding ages. The only factor that is known to increase the likelihood of a hearing loss besides common factors such as aging, disease, and certain drugs is occupational noise augmented by environmental noise exposures. For example, listening to amplified music, shooting guns, and motorcycle riding are a few of the common recreational noise exposures known to contribute to hearing loss. The auditory effects of environmental noise exposures in transit, recreation and in the household have not been studied in enough detail to determine their consequences on hearing.

### 7.1.2 What is Not Known

Although generally adequate for Federal, State and local regulatory purposes, there remain a number of unanswered questions concerning the effects of noise on hearing. Most of the data concerning the long-term auditory hazards of noise on humans come from studies of continuous steady-state occupational noise exposure. There is a lack of definitive information on the effects of shorter term intermittent noise exposures on humans which may be less harmful to hearing. Most of the knowledge concerning impulse noise comes from studies of the effects of gunfire noise, yet millions of Americans are exposed to impulse/impact noise on the job in industrial settings. Existing criteria may not fully account for time-varying noise exposures. Neither do these criteria account for what may well be additive effects of concurrent impulse noise and steady state noise exposure.

Much of the present occupational hearing loss data base is contaminated by nonoccupational noise exposures in the military, and in transportation and recreational activities. Furthermore, there is a marked deficiency in our knowledge of the prevalence of NIHL in the United States, both inside and outside of the workplace. Very little is known about the contribution of certain environmental noise source exposures and patterns of exposure on the population's hearing sensitivity. These lower level nonoccupational noise exposures should be considered when investigating the effects of occupational noise.

Although significant efforts are being made to improve our understanding of the relationship between noise exposure and hearing loss in industry, little is known about the effects of varying degrees of hearing impairment on the social and economic functioning of the affected individuals. Criteria for hearing handicap have been developed indirectly from speech discrimination tests which fall short of adequately simulating lifelike conditions. The relationships between hearing sensitivity and social functioning need to be more adequately researched. Likewise, very little is known about the secondary auditory effects of NIHL such as tinnitus (ringing in the ear), changes in loudness, and discomfort, which are highly annoying to hearing impaired persons and seem to accompany most hearing losses due to noise.

Susceptibility to noise-induced hearing loss varies considerably among individuals. Little is known about the causative factors underlying these differences in susceptibility. Little is known about the susceptibility of children to NIHL. Furthermore, current monitoring methods do not allow for the identification of persons susceptible to NIHL. It is often assumed that Temporary Threshold Shift (TTS) is correlated with susceptibility to NIHL, yet this has not been proven in humans. More sensitive tests are needed to identify the most susceptible persons so that protective measures can be introduced to safeguard their hearing as early as possible.

Properly planned studies are needed to address the interactions of noise with other stressors. There is little information describing whether poor health status, specific disease states, ototoxic drugs, or chemical agents increase predisposition to or enhance noise induced hearing loss. Further, if a high level noise exposure is voluntary and less aversive to the individual, there is little information on whether the net effect on hearing sensitivity is different.

### 7.1.3 Priorities

In the EPA document published in 1977, "Towards a National Noise Strategy," EPA identified the important goal of taking all practical steps necessary to eliminate hearing loss as a consequence of exposure in the workplace and the general environment. One area where more research is needed is the hearing loss caused by nonoccupational noise, both alone and in combination with occupational noise. Research is needed to assess the consequences of both moderate and high level nonoccupational noise source exposures on the public and to determine the contribution of specific exposures to hearing sensitivity.

Major emphasis should be placed on investigating the auditory effects of noise on children. Hearing is considered by many to be the most critical sensory experience in childhood because of language development and its implications for overall cognitive development and learning.

Another area needing study is the interrelationships between NIHL and other general health conditions of the public. Certain health conditions may interact with noise to produce reduced hearing sensitivity.

### 7.1.4 Current Research Activities

The current and planned research activities of other Federal agencies have been moderately extensive over the past few years in specific areas of NIHL research. Other Federal agencies have spent millions of dollars per year in NIHL research related to public health and welfare needs. Annual amounts spent on particular NIHL and Hearing Conservation topics between FY 1978-80 averaged approximately nearly $6 million. The Department of Defense and the National Institute of Neurological and Communicative Disease and Stroke account for about 70 percent of the spending outlay in this category. A third contributor is the National Institute for Occupational Safety and Health, with a broad multi-topic research program accounting for almost 16 percent of the funding. Only in the areas of hearing conservation methods and auditory effects of impulse noise are funding levels rising. Listing below are some of the general topical areas of NIHL research funded by Federal agencies.

- Underlying Physiologic Mechanisms of NIHL

Physiologic and biomedical research has been principally supported by the National Institutes of Health (NIH) at funding levels of approximately $1 million per year. Other agencies such as the Department of Defense (DOD) have been conducting research at much lower funding levels. NINCDS, the major sponsor of basic auditory research, is supporting major microscopic studies in several laboratories examining the anatomical, physiologic and biochemical changes in the inner ears of different animals, and correlative changes in behavioral auditory capabilities and electrophysiologic characteristics caused by different durations and levels of noise exposure.

- Refinement of Criteria for Intermittent Noise and Impulse Noise

This topic overlaps the previous one to some extent because the study of NIHL from intermittent and impulse noise necessarily includes the study of the structural, physiologic and biochemical changes in the auditory system caused by these type of exposures.

The National Institute for Occupational Safety and Health (NIOSH), the National Institute of Environmental Health Science (NIEHS), and the Department of Defense (DOD) have assumed lead responsibilities in filling the research gaps related to nonsteady-state noise and developing revised criteria for impulse and intermittent noise. Both animal studies and field research studies are being sponsored.

DOD is paying particular attention to the physiologic effects of impulse noises from military hardware with a number of laboratory and field studies. NIOSH has conducted an extensive literature search coupled with on-site industrial visits to estimate the number of American workers exposed to impulse noise. In another NIOSH field study, the hearing abilities of workers exposed to defined intermittency patterns in the paperworking industry are being quantified. In addition, the National Institute of Environmental Health Science (NIEHS) has a multielement long-term program to investigate the interactions between continuous and impulse noise and vibration using different animal models.

- Establishment of Parameters of Individual Susceptibility

NIOSH research plans specify the study of the interactive effects of noise with lead and other potentially ototoxic agents.

The U.S. Navy has also been particularly interested in hearing loss susceptibility. In two separate studies, the Navy has investigated audiometrically dichotomous groups to determine what physical, psychological or behavioral measures might account for demonstrated differences in susceptibility to hearing loss. Another Navy study is developing a high frequency audiometric procedure to enable early identification of noise-induced hearing loss. Joint EPA/U.S. Air Force studies and NIEHS investigations have assessed the susceptibility of the fetus to hearing loss using sheep and guinea pigs as surrogates for human subjects.

EPA and the U.S. Air Force have also been investigating the susceptibility of children to NIHL in an ongoing longitudinal epidemiologic study. NIEHS has been sponsoring studies to determine the consequences of early noise exposures on animal subjects by assessing differences in anatomical and physiological damage. This research is evaluating the notion of "critical periods" in auditory development when the auditory system may be more prone to damage.

- Determination of Social and Economic Impact of NIHL

The Department of Labor has recently completed a major literature review study on the technical appropriateness of different hearing impairment criteria used in workers'compensation assessments. EPA is currently supporting a small pilot study assessing some of the social and economic problems of hearing impaired workers. Studies by the Army are examining some of the communicative problems and auditory rehabilitive needs of military personnel with NIHL.

### 7.1.5 Position in the Research Continuum

As depicted in Table 7-1, NIHL research is relatively well advanced compared to some of the other research categories investigating the health effects of noise. From years of research, a systematic relationship has been developed between steady-state noise levels, the duration of exposure, and the resulting hearing loss. The statistical predictiveness of this relationship has provided a good basis for Federal occupational noise legislation. However, research has not yet accounted for wide individual variations in susceptibility to NIHL, the effect of noise with varying temporal patterns, nonacoustic intervening factors, and the social impact of NIHL.

### 7.1.6 List of Research Initiatives Necessary to Better Support Public Health and Welfare Needs

After reviewing the status of NIHL research, environmental noise program needs and priorities, and the planned research activities of other agencies and research organizations, the following list of Priority Research Initiatives are recommended for inclusion in this Plan. They cover topics which should be addressed to support environmental noise control programs with adequate criteria, but are not currently being directly addressed by other groups.

They are:

I. Determination of the prevalence of NIHL in the United States and the contribution of sociocusis (nonoccupational exposure), presbycusis (aging), and occupational exposures

II. Establishment of parameters of individual sensitivity to NIHL

III. Refinement of criteria for low-level noise exposure

IV. Determination of the social and economic impacts and other consequences of NIHL

## 7.2 Detailed Descriptions of the Research Initiatives

### 7.2.1 Priority Research Initiatives

### I. Determine the prevalence of NIHL in the United States and the contribution of sociocusis (environmental exposure), presbycusis (aging), and occupational exposures.

Description and Basic Considerations.--The objective of this Research Initiative is to isolate NIHL from other hearing loss etiologies and estimate the magnitude of the problem caused

TABLE 7-1
POSITION ON THE RESEARCH CONTINUUM - NIHL

| Research Continuum | Current State of Knowledge | | |
|---|---|---|---|
| | Adequate | Marginal | Inadequate |
| 1. Demonstrate existence of an association | x | | |
| 2. Demonstrate basic cause-effect relationship | | | |
| A. Animals | x | | |
| B. Humans | x | | |
| 3. Investigate physiologic mechanisms | | x | |
| 4. Investigate intervening factors. Improve cause-effect relationship | | | |
| A. Acoustic | | x | |
| B. Nonacoustic | | | x |
| 5. Quantify dose-response relationship | | x | |
| 6. Refinement and special populations | | | x |

by different noise source environments. In the past it has been difficult to separate the hearing loss caused by age, biological factors, societal factors and occupational noise, and to predict the hazards of noise in different environments. This research will assist in describing the extent and severity of hearing loss due to different patterns of noise source exposures and the extent of accompanying auditory effects such as communication problems and tinnitus.

In Fiscal Years 1980 and 1981, EPA initiated research in pursuit of this Initiative using data from the 1971-75 National Health and Nutrition Examination Surveys (HANES) in the areas of audiometric assessment, hearing related problems, medical examinations and demographic indices related to noise exposure. The HANES survey is periodically conducted to obtain national estimates of the health status of the population. Cardiovasculer and other health status information will be included in the analysis supportive of data requirements in other research categories. (See Nonauditory Physiologic Effects - Section 4.2.1.II.)

Expected Results.--The resulting research will attempt to (1) describe hearing related problems associated with different occupational and environmental noise exposures; (2) determine the prevalence of NIHL in the United States; and (3) develop separate sets of curves for presbycusis, sociocusis and NIHL. Preliminary findings under this Initiative should be partially completed at the end of Fiscal Year 1982. Additional work should be continued, with the aim of applying the results to source-specific assessment programs which would be useful to Federal agencies and State and local governments in support of regulatory and consumer information programs. Related research should follow up these studies using other health data bases once the EPA project is completed. Significant relationships and results from these studies should then be followed up with detailed epidemiological and human clinical research.

Results to date.--Preliminary results have shown that it is quite reasonable to apply predicted noise levels ranges to descriptive data on job and occupational categories. The results show very systematic relationships between estimated noise exposures and measured hearing losses.

## II. Establish parameters of individual sensitivity to NIHL.

### Component I. Relationship between physiologic disease and hearing loss.

Description and basic considerations.--The object of this research is to isolate relevant biologic variables and physiologic problems which are correlated with auditory difficulties. Certain health conditions and demographic factors can be analyzed to determine whether they predispose an individual to NIHL. At the present time, the HANES survey results provide the focus for this investigation. More in-depth research plans would be contingent upon the results of the HANES data analysis and the results of research being undertaken by NIH and the U.S. Navy. The Navy is conducting several investigations in an attempt to develop early tests of hearing damage and to identify susceptible individuals.

Expected Results.--Descriptive analyses should show whether there are any associations between certain health conditions, demographic factors, diseases and hearing loss. Eventually, it is hoped that a battery of psycoacoustic tests can be developed to identify early auditory signs of NIHL and separate NIHL from other sensorineural etiologies.

Results to Date.--Preliminary results from the HANES data reveal that black persons have better hearing then their white counterparts at the high frequencies of hearing, and that eye color may be related to hearing level.

### Component II. Susceptibility of special populations--children.

While environmental noise may adversely affect people of all ages, children may require special consideration and safeguards. Research with animal models indicates that younger organisms are more susceptible to NIHL than are adults. Children may also be exposed to different sources of noise not currently recognized as affecting hearing.

From 1976 to 1981, EPA in cooperation with the U.S. Air Force has sponsored a longitudinal study at Fels Research Institute of the Wright State Medical school, to analyze age-related changes in the auditory sensitivity of children, and to relate these changes to environmental noise exposures as well as to developmental and physiologic variables. This information is important in order to determine whether additional controls are necessary to reduce the noise exposure of children. Hearing level thresholds, impedance audiometry, speech discrimination and blood pressure data, together with detailed information from noise exposure, otological, recreational, and medical histories and 24-hour noise exposure monitoring printouts have been obtained serially from a group of Southwestern Ohio children. Approximately 250 children, aged 6-18, participated in this longitudinal study.

This research study should be expanded to include more sophisticated examinations of auditory and physiologic functioning. If possible, the subject population should be increased to include a larger sample of urban and minority children. The study should also be extended in time in order to gather important auditory and demographic data for the children entering the work force. If the children were followed through adulthood, it would be possible to determine whether auditory patterns and noise exposures during childhood can be correlated with hearing later in life.

NIEHS is currently sponsoring research to examine the concept of critical priods of auditory development in young animals. Follow-up research along these lines is needed to ascertain the susceptibility of very young organisms to noise-induced hearing damage.

Expected Results.--Periodic results would describe:

1. Changes in the hearing sensitivity of both children and teenagers related to specific environmental factors;
2. The consequences of a hearing loss in childhood with respect to communicative and educational problems;
3. Whether there are any critical periods where hearing sensitivity is prone to change;

4. Whether hearing threshold configurations established during childhood may be correlated with hearing ability later in life;

5. The effects of developmental and growth changes on hearing levels.

Results to Date.--Twenty-four hour noise monitoring results reveal that children are exposed to average A-weighted noise levels of 77 to 84 dB. For each sex, auditory thresholds tend to be highest at the frequencies of 4K and 6 KHz. There is a trend of increasing sex differences in mean thresholds consistent with the trend of increasing sex differences in noise exposure (higher in males). Preliminary analysis show elevations in thresholds for participants engaged in certain types of noise-related activities.

### Component III. Determine source exposures causing TTS and assess debilitating consequences.

There are many hazardous noise environments outside of the workplace which can cause temporary reductions in auditory sensitivity, commonly called TTS (Temporary Threshold Shifts). The results of TTS experiments have been used in the past to predict permanent reductions in hearing for persons with long-term occupational noise exposure. However, TTS itself may warrant special consideration where the reduction in sensitivity interferes with ongoing activities. Specifically, the activities of children should be investigated where the repeated occurrence of TTS may have deleterious effects on education, communication and performance. Field and laboratory

TTS studies with children should be conducted. This Research Initiative should assess whether there is a need to control source exposures on the basis of TTS. A pilot study on TTS from riding school buses was funded by EPA in Fiscal Year 1979.

Expected Results.--The results should be suitable for incorporation into Federal, State and local noise control programs, and public information materials for parents, the PTA and other organizations. Results would include:

1. The identification of hazardous noise conditions particular to the activities of children (e.g. riding school buses, listening to music on stereo headsets);
2. Determination of the amount of TTS caused by these common activities of children;
3. Assessment of the related consequences on education, communication, and performance.

## III. Refinement of criteria for low-level noise exposures.

Description and Basic Considerations.--Existing criteria are extrapolated from the high level noise exposures in industry to determine the related auditory risk at lower level noise exposures. Recent studies have revealed that children, homemakers and many segments of the public are exposed to noise levels in environmental settings capable of causing permanent reductions in auditory sensitivity. There is a need to more accurately estimate the lower limit of steady state and fluctuating noise levels capable of causing permanent hearing loss and incorporate such findings into comprehensive damage risk criteria.

Future HANES data analyses and other data bases (e.g., large industrial hearing conservation programs) could be used to determine specific environmental noise source exposure patterns associated with reduced hearing sensitivity. The research effort planned under this Initiative would isolate and quantify these specific low-level source exposures in a selected population and determine the contribution of these source exposure patterns on an individual's hearing sensitivity. Auditory diagnostic assessments should be conducted in conjunction with dosimetry measurements and a questionnaire program in order to meet the needs of this project.

Expected Results.--The magnitude of the auditory problems associated with specific low-level environmental source exposures would be determined. This information would assist in the development of refined hearing loss criteria.

## IV. Determination of social and economic impacts and other consequences of NIHL.

Description and Basic Considerations.--Workers compensation costs for NIHL are expected to increase by approximately $2.5 billion over the next 10 years, yet little is known about the adequacy of current hearing impairment criteria in terms of the real social and economic impacts. Although recent research activities by EPA, DOL and DOD have started to shed light on communicative problems of the hearing impaired and the scientific deficiencies of some of the present hearing impairment criteria, the real cost to the hearing impaired individual and the nation remains unknown.

Research should be undertaken to comprehensively describe the full array of problems facing the hearing impaired individual in everyday situations. Assessments should be made between the configuration, growth and magnitude of the individual's hearing loss in relation to his/her social, emotional, and economic functioning, both inside and outside of the workplace. Both field and laboratory studies will be needed under this Initiative to focus in on the real world hardships caused by NIHL. Emphasis should be placed initially on workers with hearing impairment who work in settings where auditory communication is part of the workers' responsibilties.

Expected Results.--

1. The development of the most scientifically appropriate hearing impairment criterion.
2. Information on the real cost of NIHL for use in balancing the benefits of noise control against the costs.
3. New assessment techniques for determining hearing status, speech discrimination ability, etc.

### 7.2.2 Secondary Research Initiatives:

The following Research Initiative is recommended to be undertaken by research organizations once the "priority" Initiatives have received adequate attention:

- The effects of voluntary and less aversive noise exposure on the hearing sensitivity of an individual.

Previous research has shown sizable differences in susceptibility to hearing loss. Little is known about the effect of non-acoustic or contextual factors. A series of psycoacoustic experiments might be run to determine whether voluntary exposure to high noise levels in, for example, recreational settings has the same effect on hearing as listening to undesirable sound levels in a work type setting, for comparable levels and duration of noise. The meaningfulness of the noise would be one of the important independent variables.

As discussed, other agencies such as DOD, NINCDS, NIOSH and NIEHS are addressing many other major areas of concern to environmental noise control efforts in their specific auditory research programs. Many of these programs involve long-term biomedical research projects which should be continued over the next 5-10 years, in line with the program plans that have already been established.

# 8. RESEARCH PLAN FOR
BEHAVIORAL, SOCIAL AND
PERFORMANCE EFFECTS

## TABLE OF CONTENTS

Contents | Page

8.1 Rationale for Selecting Specific Research Initiatives 8-1

  8.1.1 What is Known 8-1

  8.1.2 What is Not Known 8-3

  8.1.3 Priorities 8-5

  8.1.4 Current Research Activities 8-5

  8.1.5 Position on the Research Continuum 8-7

  8.1.6 List of Research Initiatives Necessary to Better Support Public Health and Welfare Needs 8-7

8.2 Detailed Descriptions of the Research Initiatives 8-9

  8.2.1 Priority Research Initiatives 8-9

    I. Effects of Noise on Cognitive and Social Development 8-9

    II. Behavioral and Social Adjustment to Noise 8-10

  8.2.2 Secondary Research Initiatives 8-12

# 8. RESEARCH PLAN FOR BEHAVIORAL, SOCIAL AND PERFORMANCE EFFECTS

## 8.1 Rationale For Selecting Specific Research Initiatives

The long-term objective of research under this category is to determine the effects of noise on social behavior, mental health and human performance.

### 8.1.1 What is Known

The behavioral, social and performance effects category is a very broad category encompassing most aspects of personal and social adjustment and performance. These effects are often complex, subtle and indirect, and the result of complex interactions with nonacoustic variables.

By a wide margin, the greatest amount of scientific attention has been devoted to relatively short-term laboratory investigations (typically exposures of one hour or less) of the performance of mental and motor tasks under noise. Unfortunately, findings to date have been quite ambiguous and controversial. Although no direct, simple statements are possible, some rather general conclusions can be drawn.

It is probably safe to conclude that few performance decrements occur under steady state noise when the level is below 80 to 90 dB. A number of studies have shown that exposure to unpredictable or aperiodic intermittent noise may result in more pronounced performance effects, even at levels considerably below 80 to 90 dB. Changes in the prevailing noise level may also have an adverse effect on performance.

Tasks that require simple, repetitive operations are usually unaffected and sometimes even improved by the presence of noise. On the other hand, most performance decrements have been found on complex tasks that require continuous activity, prolonged attention, or the accomplishment of two or more simultaneous tasks. Noise has often been found to increase the variability of performance, and to reduce the accuracy rather than the overall rate of performance.

Research has shown that motivational and personality variables can influence the effects that noise will have on performance. A fairly recent series of studies demonstrated that although performance may be unaffected during noise exposure, impairments may occur after the noise stops. It has also been demonstrated that providing the individual with the perception of control over the noise resulted in the elimination of these effects. These findings suggest the importance of contextual and other nonacoustic variables in influencing performance under noise.

A small amount of laboratory research suggests that noise may have an adverse effect on certain aspects of social behavior. There has been work on the relationship between noise and social conformity, aggression, verbal disinhibition, and altruistic (helping) behavior.

There is a growing body of evidence which shows that noise adversely affects the learning and cognitive development of children. Studies have shown that auditory discrimination and reading achievement are adversely affected in children attending school or residing in high noise environments. Evidence suggests that children may constitute a particularly susceptible subgroup with respect to the effects of noise. These studies represent some of the few attempts to assess long-term performance effects.

There have been a few other scattered attempts to assess the long-term effects of noise in field settings. There is some evidence of decreased productivity and increased absenteeism and accidents among workers exposed to high noise levels on the job. Some correlational research has also been performed on the relationship between noise exposure and mental hospital admissions, showing increased admission rates in high noise environments. Social survey work has revealed positive associations between the noise levels and various symptoms of psychological stress and negative affective states.

### 8.1.2 What Is Not Known

Thus far, no direct cause-effect relationships have been derived that quantitatively express the effects of noise on performance or other kinds of behavior.

A major stumbling block to progress is that there are few, if any, direct effects of noise on performance. Under most circumstances, it is not possible to predict effects by relying only on information concerning the physical parameters of the noise. Although we have acquired some knowledge of the connection between noise and performance, the exact relationship is quite complex and often dependent upon many elusive nonacoustical parameters such as the demands of the task, intervening factors of the performance situation, and the presence of intrinsic personality variables. Identification, description and quantification of the many nonphysical parameters is clearly required before a concern with performance as disrupted by noise will become a critical factor in influencing the nature, direction and stringency of noise control programs.

Precise data are needed on the effects of noise on the cognitive and social development of children. Noise does appear to interfere with the acquisition of important language and reading skills.

It is not known with any certainty, the extent to which noise may adversely affect work performance and social behavior in real world situations. If people are forced to cope with noise, the question is what, if any, are the costs incurred as a result of the extra effort required to function under noise? Are there effects which occur after the noise is no longer present? Research is needed to determine whether existing laboratory findings are generalizable to natural settings.

Information is lacking on the relationship between noise and social and behavioral pathology. Methodologically sound studies in this area are needed. Very little is known about individual differences in sensitivity to noise. Research is needed to help explain the observed large variability in individual sensitivity to noise.

### 8.1.3 Priorities

As pointed out previously, there is ample support for the contention that information on the behavioral effects of noise is of direct importance to the Federal, State and local noise control effort. The potential adverse behavioral effects of noise are great and include not only unnecessary disruption of productivity but also accidents on the job, absenteeism, effects on learning, social behavior, and increased social problems. At present, quantified dose-response relationships between noise and adverse behavioral, social and performance effects are completely lacking. However, there are promising avenues along which future research should be directed.

Taking into consideration probable resource constraints, relatively little research can be adequately carried out in this health effects category over the five-year period. Based on programmatic needs and other factors, emphasis should be placed on investigating the effects of noise on children and studies of behavioral and social adjustment to long-term noise exposure.

### 8.1.4 Current Research Activities

EPA has not recently sponsored any research in the behavioral category. The amount of related activity by other Federal agencies has also been less than adequate. According to the information gathered to date in the update of the Panel Report, overall funding levels may have declined in this category of research. Moreover, with few exceptions, much of the ongoing research does not seem to be directly applicable to everyday environmental noise problems.

Some of the most recent or ongoing research activities include the following:

- The Department of Defense (DOD) is assessing the performance effects of noise (and other environmental stressors) in military situations. Some of the findings of these studies may be applicable to the quantification of the effects of noise on the performance of mental and psychomotor tasks.
- The National Institute of Mental Health (NIMH) has investigated personal adjustment to urban noise in a community setting.
- The National Science Foundation (NSF) and the National Institute of Environmental Health Sciences (NIEHS) have sponsored a study on the effects of environmental noise (principally from aircraft) on children's attentional strategies and generalized expectations concerning personal control.
- The State of California is completing a large study on the achievement test scores of elementary school children in schools near freeways.

### 8.1.5 Position on the Research Continuum

From Table 8-1, it is clear that compared to some of the other health effects research categories, research in many facets of the behavioral category is still in the exploratory phase. With the exception of laboratory studies of task performance, suspected effects have been identified, but not sufficiently investigated.

### 8.1.6 List of Priority Research Initiatives Necessary to Better Support Public Health and Welfare Needs

I. Effects of noise on cognitive and social development

II. Behavioral and social adjustment to noise

These two topics have been selected for study because they represent areas in which exploratory research has produced findings suggesting potentially serious and widespread effects. Evidence exists which indicates that noise exposure may impede the acquisition of important language and reading skills in children. Other research suggests that having to cope with environmental noise can produce a number of disruptive effects on social and psychological well-being.

TABLE 8-1

POSITION ON THE RESEARCH CONTINUUM - BEHAVIORAL, SOCIAL AND PERFORMANCE EFFECTS

| Research Continuum | Current State of Knowledge | | |
|---|---|---|---|
| | Adequate | Marginal | Inadequate |
| 1. Demonstrate existence of an association | | X* | |
| 2. Demonstrate basic cause-effect relationship | | | |
| 3. Investigate physiologic mechanisms | | | X |
| 4. Investigate intervening factors. Improve cause-effect relationship | | | |
| A. Acoustic | | | X |
| B. Nonacoustic | | | X** |
| 5. Quantify dose-response relationship | | | X |
| 6. Refinement and special populations | | | X*** |

---

* Task performance studies only

** Much research in this area has established that nonacoustic factors have a strong influence in most aspects of this category.

*** Generally inadequate, but research indicates that noise does interfere with the acquisition of important language and reading skills in children.

## 8.2 Detailed Descriptions of the Research Initiatives

### 8.2.1 Priority Research Initiatives

### I. Effects of noise on cognitive and social development

Description and Basic Considerations.--A growing literature exists which indicates that environmental noise is associated with impaired speech discrimination or understanding, reading achievement, problem solving, and task performance in children. This research has involved infants through young adolescents, and has dealt with noise in both home and school environments. Other research exists which suggests that certain groups of special children may be even more sensitive to noise than normal children.

The purpose of this Initiative is to determine the extent to which living or attending school in high noise areas has adverse effects on cognitive and social development.

Phase I--In the first phase, an appraisal of the existing data should be carried out, using not only noise studies *per se*, but other relevant studies as well. A fairly extensive literature base reveals the importance of early environmental stimulation on the development of both animals and humans. Other research has dealt with the concepts of selective attention and distraction in children, particularly with respect to learning and performance in educational settings.

Phase II--In the second phase, a lab and/or field study should be conducted, incorporating the following factors in its design:

- Socioeconomic characteristics (age, race, sex)
- School performance (in-class performance, homework performance, standardized tests)
- Social behavior (in home; at school)
- Acquisition of speech and language
- Performance of selected tasks (psychomotor, cognitive).

Expected Results.--The results of the first-year appraisal will be used to finalize the protocol for the lab and/or field study in Phase II. The study should yield some of the information necessary for deriving quantitative dose-response criteria including speech communication criteria for children.

The NSF/NIH-NIEHS-sponsored study and the State of California study of the effects of highway noise on children are both yielding information suggesting the importance of research in this area. The findings from these studies should be available for input into the design of the planned research.

## II. Behavioral and social adjustment to noise

Description and Basic Considerations.--Many of the behavioral effects of noise are complex, subtle and indirect. Although it is widely accepted that noise has disruptive effects, little is known about how people adapt to and cope with noise in their environment.

Research under this Initiative should assess and quantify some of the major adverse effects of noise on social and personal adjustment.

The emphasis should be on methodologically sound studies of long-term adaptation to noise. Attempts should be made to assess the social and behavioral costs of adaptation and, where warranted, to assess the generalizability of laboratory findings to naturally occurring situations.

In the first phase, the literature should be reviewed and evaluated to 1) determine which areas of behavioral and social adjustment offer the most promise in providing criteria and 2) the specific research questions that need to be addressed. Research studies should then be designed and implemented under the second phase of this Initiative.

Expected Results.--Results of the literature appraisal can be used to decide which topics should be selected, and in designing the specifics of the research studies planned for the following years. These studies should provide preliminary data on the behavioral and social costs of long-term noise exposure. These results should also serve to validate some previous laboratory findings which indicate adverse effects of noise exposure on a number of social and interpersonal behaviors. This research should also provide an initial test of the numerous theories which have explained many of our social ills as being the result of living in environments characterized by stimulus overload: noise, crowding, time pressures, etc.

The NIMH sponsored study is yielding some data relevant to this Initiative. Preliminary results indicate that wide individual differences exist in sensitivity to noise. Hopefully, this study will identify some of the variables which explain these differences, so that they may be tested in the research planned for this Initiative.

### 8.2.2 Secondary Research Initiatives

These are topics not discussed in detail in this Plan, but are recommended to be undertaken by research organizations once the "priority" Research Initiatives receive adequate attention. These include:

- The effects of noise on social and behavioral pathology

  Several controversial and well-publicized studies have reported statistical associations between noise exposure, mental hospital admissions and other indices of mental health problems. A rather sizeable social survey literature indicates that noise exposure in the residential environment is linked to adverse subjective responses and general dissatisfaction with the quality of life.

- Individual differences in sensitivity to noise

  It is widely known that individuals differ greatly in their sensitivity to noise. However, little information is available which explains these differences. Identification of the determinants of these differences is needed in order to facilitate more valid predictions of individual and community response to noise.

- The relationship between noise exposure and worker productivity

  Some existing data suggests that exposure to high noise levels in the occupational setting may lead to reduced productivity, and increased rates of absenteeism and accidents. Other preliminary data indicate that high workplace exposures may also impair post-work, family and other interpersonal interactions.

- The role of various acoustic and nonacoustic factors on performance

  Considerable effort has been given to studying the effects of noise on performance, yet no quantitative performance criteria are available at present. Precise and systematic research is required in order to determine the contribution of important acoustic parameters, task and skills characteristics, and selected subject variables to the production of performance decrements.

- The interaction of noise with other stressors

  In the typical environmental situation, noise seldom occurs alone. Noise acting in combination with other physical and psychosocial stressors may interact in a synergistic fashion producing effects much greater than would be expected from the effects of the two stressors taken separately.

# 9. RESEARCH PLAN FOR COMMUNICATION INTERFERENCE

# TABLE OF CONTENTS

Contents — Page

9.1 Rationale for Selecting Specific Research Initiatives 9-1

- 9.1.1 What is Known 9-1
- 9.1.2 What is Not Known 9-2
- 9.1.3 Priorities 9-3
- 9.1.4 Current Research Activities 9-5
- 9.1.5 Position on the Research Continuum 9-6
- 9.1.6 List of Research Initiatives Necessary to Better Support Public Health and Welfare Needs 9-6

9.2 Secondary Research Initiatives 9-8

## 9. RESEARCH PLAN FOR COMMUNICATION INTERFERENCE

### 9.1 Rationale for Selecting Specific Research Initiatives

The long term EPA objective for research on Communication Interference is to determine and quantify the effects of noise on communication and its developmental, social and other implications.

### 9.1.1 What is Known

The ease with which normal-hearing adults can communicate with each other face-to-face, or understand speech over communication systems such as telephones, intercoms, radios, and the like, is governed primarily by the amount and type of background noise present in the environment. Although individuals can compensate to some degree for the interference created by masking noise by raising their voices, or by listening more carefully, such compensation is often tiring and unpleasant and, in extreme background noise conditions, ineffective.

Most research on the adequacy of speech communication was initially conducted in the context of evaluations of military communication systems. More recently, this body of knowledge has been applied to the slightly different problem of determining the effects of environmental noise on face-to-face communication. The fundamental tools used for assessing the acceptability of speech communication are procedures for estimating speech intelligibility in assumed background noise spectra and speech levels. A number of efforts have been made to equate percentages of words and sentences correctly understood within fixed contexts using typical speech and noise characteristics.

EPA has developed and published in the "Levels Document"* general purpose criteria relating levels of continuous noise to percentage of sentence intelligibility at specific distances under normal, face-to-face speaking conditions. One set of criteria exists for indoor speech interference and one for outdoor speech interference. These criteria are judged to be adequate for most Federal, State or local noise control purposes. In addition, criteria exist for intelligibility where the speaker has exerted greater vocal effort to overcome perceived background noise, for cases where the communications are perceived by the speaker as "vital" or "not vital".

### 9.1.2 What is Not Known

Although the major acoustic determinants of speech interference are well known, the assessment of the quality of face-to-face verbal communication is not yet a routine matter. Furthermore, the nonacoustic circumstances of the communication situation have not yet been reduced to a manageable set of standard conditions. For example, it is not yet known at what distances people actually choose or attempt to communicate indoors, outdoors, and in other special environments (schools, transportation vehicles, public meeting places, group gatherings, etc.).

---

* Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, U.S. EPA 550/9-74-004, March 1974.

Similarly, the degree to which other non-standard conditions affect speech intelligibility (such as non-native or inexperienced, or very young, old, or hearing-impaired speakers or listeners) are not yet usefully quantified. By the same token, it is not yet known how unusual background noise conditions (such as intermittent high level or time varying noise) affect satisfaction with speech communication.

Additional gaps exist in our knowledge of the indirect effects of communications interference. These include: effects on education, safety and the quality of everyday social interactions. There are numerous anecdotal reports of noise interference in the classroom. Likewise, there are reports of accidents and safety hazards in a number of different traffic and industrial situations due to the masking of emergency signals. None of these less direct effects of communications interference by noise has been quantified.

### 9.1.3 Priorities

To protect the public health and welfare from the adverse effects of environmental noise, research must now focus on refined criteria which will be helpful in assessing the effects of noise on special subpopulations, the effects of special noise patterns on the population, and the indirect effects of noise on safety, productivity and performance.

From the point of view of environmental noise control programs, therefore, the most useful specific directions for work refining criteria are to:

- Establish criteria for special groups (elderly, children, hearing-impaired, people speaking English as a second language)
- Establish criteria (families of dose-response curves) for
    - relaxed vocal effort indoors
    - relaxed vocal effort outdoors
    - relaxed vocal effort inside transportation vehicles
- Establish better criteria for time-varying noise.

In addition, the indirect adverse effects of disruption of speech by noise need to be better understood. These include the question of safety, extreme annoyance, disturbance of normal activities such as domestic life or learning, and effects on social interaction. Of particular interest, and already addressed by a Research Initiative in the "Behavioral, Social and Performance Effects" Plan, is the determination of the effects of noise on teaching and learning activities. Thus, it can be seen that the understanding of communication interference is a necessary aspect of work in some of the other research categories.

## 9.1.4 Current Research Activities

EPA has provided indirect support in this category through the Fels longitudinal study. (See Noise-Induced Hearing Loss Category, Section 7.2.1.II.) The speech discrimination abilities of children with different hearing abilities are being investigated under different noise conditions.

Other Federal agencies are much more directly active in this category. Over $1 million has been spent by other agencies on various communication interference projects over the last few years. Three agencies are significantly involved in investigating the effects of noise on the speech perception of special groups of people. Some of the specific research activities include the following:

- The National Institute of Neurological and Communicative Disorders and Stroke (NINCDS) has sponsored most of the research. Their research includes studies of speech perception problems of children and the hearing-impaired.

- The Veterans Administration has been investigating the acoustic needs of aphasics (persons with neurologically damaged language function).

- The National Institute of Environmental Health Sciences (NIEHS) has sponsored studies of the effects of time-varying noise on communication interference of people with special hearing problems.

- In addition, branches of the Department of Defense are continually undertaking research studies in assessing and redesigning speech communication systems for maximum communication effectiveness and the least interference by noise.

### 9.1.5 Position on the Research Continuum

General criteria have been achieved, and work is now proceeding on refined criteria and factors related to special populations (See Table 9-1).

### 9.1.6 List of Research Initiatives Necessary to Better Support Public Health and Welfare Needs

No Research Initiatives have been prioritized for funding under this category because of 1) assumed budgetary resource constraints over the next few years and 2) the similar research needs under other research categories. That is, some of the work required to refine existing communication interference criteria will be carried out under several of the Initiatives listed in other research categories. For example, research will be undertaken under Initiative I of the "Behavioral, Social and Performance Effects" Plan, to better understand the effects of noise on learning. As such, preliminary work should be conducted

## TABLE 9-1

## POSITION ON THE RESEARCH CONTINUUM - COMMUNICATION INTERFERENCE

| Research Continuum | Current State of Knowledge | | |
|---|---|---|---|
| | Adequate | Marginal | Inadequate |
| 1. Demonstrate existence of an association | X | | |
| 2. Demonstrate basic cause-effect relationship | X | | |
| 3. Investigate physiologic mechanisms | | NA | |
| 4. Investigate intervening factors. Improve cause-effect relationship | | | |
| A. Acoustic (impulse, intermittent) | | X | |
| B. Nonacoustic (situational factors) | | | X |
| 5. Quantify dose-response relationship | X* | | |
| 6. Refinment and special populations | | | X |

---

* Adequate for normal-hearing adults only under ideal listening contexts.

towards developing speech criteria for children. Likewise, research will be conducted under Initiative IV of the Noise Induced Hearing Loss Category to determine the social impact of hearing loss. One of the greates impacts is in the disruption of speech communication.

## 9.2 Secondary Research Initiatives

Listed below are the Secondary Research Initiatives that are recommended to be undertaken to support health and welfare needs once the "priority" Initiatives in other research categories have received adequate attention. If the research in other categories pertaining to communication interference is successfully completed, then progress will have been made towards meeting some of the work requirements under these Secondary Research Initiatives.

### I. Speech intelligibility for special groups

Special dose-response criteria are needed for the elderly, children, and the hearing-impaired (both listeners and speakers) and for the intelligibility of dialects and speech as spoken by non-native speakers. Of particular importance is more work on the communication problems of the hearing-impaired in the presence of noise. Of all the topics listed in these four Initiatives, this topic warrants special and timely research attention. Research under the "Noise Induced Hearing Loss" and "Behavioral, Social and Performance Effects" Plans will contribute to meeting the research needs of this Initiative.

## II. Relaxed conversation in different environments

Under this Initiative are included criteria for relaxed conversation indoors, outdoors, and inside transportation sources (cars, trains, buses, aircraft, etc.).

## III. Effect of time-varying noise on speech intelligibility

The effects of time-varying noise of various types (e.g., vehicular passbys, aircraft overflights, and periodic sources) need to be studied in laboratory conditions to develop appropriate criteria.

## IV. Communication interference effects in high-noise work and traffic environments

The objective of this Initiative is the eventual quantification of risk from accidents caused by failure to hear warning signals, of loss of productivity, and decrements in performance where auditory communication is required. As such, the contents of this Initiative are similar to and partly covered by the Initiatives to be pursued under the "Behavioral, Social, and Performance Effects" Research Plan.

# CHAPTER 10

# SUMMARY AND INTEGRATION

The purpose of this chapter is to pull together information on the proposed Research Initiatives, so that the total array of research activities and research milestones can be identified, compared, and discussed across all of the health effects categories. The chapter ends with a short discussion of the interaction of this Plan with ongoing environmental noise activities.

## 10.1 Research Initiatives in Which Work is Currently in Progress

Table 10-1 displays the Research Initiatives in each research category that have been funded by EPA in Fiscal Year 1981, the first year of the Five Year Research Plan. Some of the related research activities were initiated in Fiscal Year 1980, and received additional support in Fiscal Year 1981. Detailed discussions of these Initiatives are provided in Chapters 4 to 7.

As shown, most of the identified research is in the Nonauditory Physiologic Research Effects category; specifically addressing the effects of noise on the cardiovascular system. Over 50 percent of the EPA noise effects research effort involves cardiovascular related research. The high degree of EPA effort within this particular research category is due to the great health implication of such effects, the small amount of related research to date, and the requirements for conducting multidisciplinary biomedical research. It should be noted,

## TABLE 10-1

## RESEARCH INITIATIVES RECEIVING EPA SUPPORT IN FISCAL YEARS 1980 - 81

| PRIORITY | INITIATIVES |
|---|---|
| A | NONAUDITORY PHYSIOLOGIC EFFECTS |
| | I Animal experimental studies on the relationship between noise, elevated blood pressure and other cardiovascular effects. |
| | Component I - Preliminary investigations and methodological refinements |
| | Component II - Investigation of acoustic and nonacoustic factors |
| | II Epidemiologic studies on the relationship between long term noise exposure and adverse cardiovascular effects. |
| | Component I - Retrospective Analysis |
| | III Human studies and clinical investigations of cardiovascular and neuroendocrine responses to noise. |
| | Component II - Investigation of differences in susceptibility |
| B | SLEEP DISTURBANCE |
| | II Health consquences of noise-disturbed sleep. |
| B | INDIVIDUAL AND COMMUNITY RESPONSE |
| | I Determination of magnitude of community and individual response attributable to specific sources of noise. |
| | Component I - Construction Noise |

## TABLE 10-1

## RESEARCH INITIATIVES RECEIVING EPA SUPPORT IN FISCAL YEARS 1980 - 81
(CONTINUATION)

| PRIORITY | INITIATIVES |
|---|---|
| C | NOISE-INDUCED HEARING LOSS |
| | I Determine the prevalence of NIHL in the U.S. and the contribution of sociocusis (non-occupations NIHL), presbycusis (aging) and occupational hearing loss. |
| | II Establish parameters of individual sensitivity to NIHL. |
| | Component I - Susceptibility of special populations - children |

as mentioned, that a Detailed Cardiovascular Research Plan has recently been drawn up describing the entire program of needed research to determine the extent to which a basic cause-effect relationship exists between noise and cardiovascular problems, as well as to develop dose-response criteria for regulatory purposes.

The reader should note that many of the specific Research Initiative components implemented by EPA in Fiscal Year 1981 were designed to be the first steps in a series of animal and human clinical studies and epidemiologic investigations in pursuit of criteria development. Standing alone, the results of individual research projects/components will not, for the most part, yield the type of definitive information needed to support noise control actions unless substantial research is undertaken in line with the conceptual framework established in the "Research Continuum" (see Chapter 3, Section 3.4). The identified Research Initiatives should be undertaken in a comprehensive and coordinated research effort.

## 10.2 Integrated Schedule of Expected Results

The successful execution and management of the Plan requires, among other things, monitoring the progress of the various activities undertaken during the Plan period. An important aspect of this task involves knowing when to expect the results from a particular Initiative or component, and knowing what the results of each Initiative are expected to reveal. This is particularly important since results from completed Initiatives or components will be used in the design and specification of others. A high degree of interdependence exists, making the careful sequencing and timing of the Initiative within each noise-related health effects category of critical importance.

An overview of the anticipated schedule of expected results can be found in Table 10-2. The Table lists the Initiatives and components which are expected to be completed at the end of Fiscal Year 1982, and describes the results expected with the successful completion of each Initiative. Similarly, Table 10-3 provides a short description of the results expected after the successful completion of work under the full array of Research Initiatives identified in this Plan within approximately a five-year time frame. The real time frame in which related results will become available is of course dependent on the committment of resources of interested Federal agencies, etc. The results of these completed Initiatives would then be available for Federal, State, or local noise program application and for determining the direction of future research activities.

## 10.3 Interaction of Proposed Research with Ongoing Noise Control Activities

The foundation of success in controlling environmental noise is dependent upon an adequate health and welfare information base. Noise control actions at the Federal, State and local governmental levels as well as individual efforts undertaken by the private sector and the public, are founded on the same underlying need: to improve the quality of the noise environment and protect the public health and welfare. Federal, State and local officials and the public must

## TABLE 10-2

## INTEGRATED SCHEDULE OF EXPECTED RESULTS BY THE END OF FISCAL YEAR 1982

END OF
FISCAL YEAR 1982

| Research Initiatives | Results |
|---|---|
| NONAUDITORY PHYSIOLOGIC EFFECTS | |
| Animal Experimental Studies<br>o Preliminary Investigations and Methodological Refinements | Expansion and refinement of findings showing a relationship between noise exposure and alterations in blood pressure and other cardiovascular parameters. |
| Epidemiologic Studies<br>o Retrospective Analysis | Systematic analysis of foreign and U.S. epidemiologic research on the cardiovascular effects of noise. Recommendations forthcoming for a program of epidemiologic research. |
| Human Clinical Studies<br>o Acoustic and Nonacoustic Factors | Initial study of human component segment completed. Initial assessment of the relationship between noise stress and aspects of cardiovascular function in human subjects. |
| SLEEP DISTURBANCE | |
| Health Consequences of Noise Disturbed Sleep<br>o Human Studies | Initial phase of research completed, resulting in the identification of health and performance measures offering the greatest promise in portraying the consequences of disturbed sleep. The resulting measures are to be used in the next series of investigations. |

## TABLE 10-2
## INTEGRATED SCHEDULE OF EXPECTED RESULTS BY THE END OF FISCAL YEAR 1982

(CONTINUATION)

END OF
FISCAL YEAR 1982

| COMMUNITY AND INDIVIDUAL RESPONSE | Results |
|---|---|
| Specific Sources of Noise<br>o Construction Noise | Completion of the test plan for construction site attitudinal and physical noise measurement surveys in both residential and non-residential areas. |
| NOISE-INDUCED HEARING LOSS | |
| Parameters of Individual Sensitivity<br>o Children | Preliminary results describing changes in the hearing sensitivity of children and teenagers related to specific environmental factors. |
| Prevalence of NIHL in the U.S. | Preliminary results describing hearing-related problems in the U.S. associated with different occupational and environmental noise exposures. |

## TABLE 10-3

## INTEGRATED SCHEDULE OF EXPECTED RESULTS AFTER RESEARCH INITIATIVES ARE COMPLETED
(WITHIN APPROXIMATELY FIVE-YEAR TIME FRAME)

| Research Initiatives | Results |
|---|---|
| NONAUDITORY PHYSIOLOGIC EFFECTS | |
| Animal Studies | Interim results available providing basic information necessary to derive tentative dose-response criteria. |
| Epidemiologic Studies | |
| o Prospective Analysis | Interim results available from small scale prospective study providing a test of the causal-relationship between noise and hypertension, controlling for major confounding variables. |
| o Special Populations - Blood Pressure in Children | Interim results available concerning the extent to which environmental noise contributes to childhood blood pressure elevations. |
| Human Studies and Clinical Investigations | |
| o Acoustic/Nonacoustic | Results available demonstrating the extent to which specific acoustic and nonacoustic factors alter cardiovascular system response. |
| o Susceptibility Differences | Results available examining the susceptibility of selected sub-populations. |
| Other Nonauditory Physiologic Effects | |
| o Selected Studies | Preliminary results available from several of the most important non-auditory physiologic effects topics (other than cardiovascular.) |

TABLE 10-3

INTEGRATED SCHEDULE OF EXPECTED RESULTS AFTER RESEARCH INITIATIVES ARE COMPLETED (WITHIN APPROXIMATELY FIVE-YEAR TIME FRAME)

(CONTINUATION)

| | |
|---|---|
| SLEEP DISTURBANCE | |
| Relationship Between Field and Laboratory Data | Refined criteria available to predict the magnitude of noise-related sleep disturbance in the home environment. |
| Health Consequences for Noise-Disturbed Sleep | Interim results available to objectively define and quantify, in a preliminary manner, the impact of noise-disturbed sleep on general health and performance. |
| Acoustic Parameters Related to Sleep | Interim results available providing a family of sleep disturbance criteria for different noise characteristics and sources. |
| COMMUNITY RESPONSE | |
| Specific Sources of Noise | Interim results available. Dose-response criteria of limited application for two specific noise sources and exposure conditions selected on the basis of environmental noise program requirements. |
| Specific Acoustic Attributes | Interim results available. Preliminary adjustment methods or predictors for two specific acoustic attributes selected on the basis of environmental program requirements. |
| NOISE-INDUCED HEARING LOSS | |
| Determine the Prevalence of NIHL in the U.S. | Separate sets of curves available describing magnitude of hearing related problems in the U.S. associated with occupational noise, presbycusis (aging), and sociocusis (environmental noise). |
| Parameters of Individual Sensitivity<br>o Susceptability of Children | Interim results available providing a description of the changes in hearing sensitivity of children related to specific noise exposures and the determination of related communication consequences. |

TABLE 10-3

INTEGRATED SCHEDULE OF EXPECTED RESULTS AFTER
RESEARCH INITIATIVES ARE COMPLETED
(WITHIN APPROXIMATELY FIVE-YEAR TIME FRAME)

| | |
|---|---|
| o TTS and Children | Determination of source exposures causing TTS in children and the interim assessment of debilitating consequences. |
| Refinement of Low Level Noise Criteria | Interim results available providing refined hearing loss criteria for low-level noise exposures which describe the magnitude of auditory problems associated with environmental and occupational noise. |
| Social Impact of Hearing Loss | Initial quantification of some of the problems facing the hearing impaired in everyday situations. Determination of most appropriate study designs for more comprehensive assessments. |
| BEHAVIORAL, SOCIAL AND PERFORMANCE | |
| Cognitive and Social Development | Interim results available in the determination of the extent to which living or attending schools in high noise areas has adverse effects on the cognitive and social development of children. Should result in preliminary criteria for children. |
| Behavioral and Social Adjustment | Preliminary results available assessing and quantifying some of the adverse effects of noise on social behavior and performance. |

be adequately informed of the health consequences of noise in order to secure a healthy noise environment in a cost-efficient manner.

The Research Plan discussed heretofore represents a balanced approach, with objectives to both (a) refine existing health effects criteria and expand the health effects data base, and (b) perform integral research that is necessary to develop new criteria that may be of more direct importance to human health. For example, the Research Initiatives in the highest prioritized category, Nonauditory Physiologic Effects, may very well yield information describing much more serious noise-related health problems than are currently assumed. EPA recognizes that significant gaps exist in our understanding of the health effects of noise. These deficiencies can only be filled through a comprehensive and intense program of relatively long-term research.

## 10.4 The Future

In summary, if the research programs presented in the Research Plan are undertaken, it is expected that the findings will increase our understanding of the health effects of noise and enhance our ability to properly ascribe health benefits to noise control actions taken at the Federal, State and local levels of government. The result will be a more healthy and livable environment achieved in a cost efficient manner. Moreover, the present Research Plan should ultimately produce results, particularly in the category of Nonauditory Physiologic Effects, which may refocus and redirect Federal, State and local noise control efforts. The first steps of noise effects research should be undertaken if the answers to outstanding noise-related health effects questions are to be forthcoming. Research must precede application, especially in the complex health effects area, which have previously only received scattered scientific attention.

A comprehensive Research Plan with well defined objectives is the first and most important part of the research process. It is hoped that other agencies and organizations will use this Plan as a source of guidance in developing their own respective research plans. A more integrated Federal research planning process will maximize the chances for meeting the goals and objectives set forth in this Plan.